FROM GARAGE INVENTOR TO GARAGE ENTREPRENEUR

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ABSTRACT

Kevin Anthony Miceli: From Garage Inventor to Garage Entrepreneur
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The American garage serves as the backdrop for the image of the independent entrepreneur. However, literature highlights the importance of resources for entrepreneurs that are derived from experience in firms, universities, or markets. This dissertation investigates how theories from those entrepreneurship studies can be applied in the context of independent ("garage") invention that results in garage entrepreneurship. In studying the process used by garage entrepreneurs, it elucidates how the technological, social, and geographical opportunity spaces present in the pre-venture period could affect the decision to form a new venture.

Using data of non-affiliated technologies from the USPTO during 1975–2009, I analyze inventors and technologies that are at risk of forming a firm in order to understand which characteristics increase the likelihood of entrepreneurship given prior technological development. In the data, I identify a risk-set of 152,092 inventors who will start 5,684 new firms. I find that the nature of the opportunity spaces through competition and resources is associated with the transition from inventor to entrepreneur and increased experience and network strength can substitute for organizational affiliation. Finally, while all inventors in this study start independently in the metaphorical garage, those who transition to an existing company are more likely to spin back out after experience in smaller firms and twice as likely to start a new firm as those who do not join an existing organization.

Keywords: independent inventors; technological entrepreneurship; opportunity spaces; technological evolution; entrepreneurial spin-outs

Dedicated to my family:

My wife, Caroline,

And my children, Logan and Connor

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Someone once told me that you should write with the end in mind. This section is the last part of my dissertation to be written and I have frequently said that I looked forward to writing such acknowledgments. That excitement and longing was true not only because it meant that I will have written a dissertation at the point, but because I have longed to express my immense gratitude and love for the people who have made this possible. Even before it was done, I have long wanted to recognize their support.

I want to thank my family. In particular, my incredible spouse and partner, Caroline. “Acknowledgments” and “thanks” cannot even begin to express my feelings towards Caroline as I conclude the PhD. She has supported me whole-heartedly through all of this. It is going on seven years since I told her that I wanted to quit my job, move, and go back to school for a full-time MBA program. And as soon as I got back into school, I thought about staying to earn a PhD. This was not intended to be a two-year/five-year bait-and-switch, even though she will joke about that sometimes. After all this time, I still do not know what to say to her. We have journeyed together through time and space and I believe it has been incredible. Caroline has supported me, kept our lives organized so I could do what I needed, and has been raising our two loving children. She has made everything in our life possible. Certainly this dissertation would not be what it is without her.

Next, my children, Logan and Connor. They kept me honest as I managed my time. I needed to be home at 5:30 so I could have dinner and do bath time and read for bedtime with them. That time was important. That time was precious. I had to be efficient at work.

The evenings were mostly protected for this reason. They also knew this was temporary and encouraged me with the things we will do "when daddy graduates," while still offering me smiles, laughter, requests for train time, and enjoyment of our life right now.

While Logan was technically born before I went back to school while I was still working at GE, essentially his entire life so far has been lived with me in school. This journey has been more meaningful to me because he has been with us. Logan has journeyed through all the different cities, states, countries, schools, houses, and apartments. Connor was a gift during the doctoral program. The benefits of academic life were reinforced as I could stay home with him when needed or he could come with me. Connor has come to school with me when necessary, enjoying blue lollipops and the occasional iPad time, and played dinosaurs and trains when we met Atul at his house. He has dissertated with me much more than he realizes.

Besides my family, I would like to acknowledge the incredible support of my advisor, Atul Nerkar. Once again, the word "acknowledge" seems too cold for what Atul has given me. He has challenged me to really become a scholar and pushed me to do more and think harder about our problems. He loves this career. He loves the academic freedom. He loves the questions we can ask and the possibility of data that can answer those questions. The excitement he has for our research is incredible. Atul has certainly given me so much over the course of the program: academic and moral support, his time, good coffee, and the occasional ride to and from school, to say the least. And at the end of the day, Atul has called me a colleague. I thank him for all of that and more. He has always pointed out that the dissertation represents only the start of an academic career. And I can only hope to live up to his expectations going forward.

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Finally, I would like to thank my parents, Susan and AJ Miceli. They instilled a love of education and the pursuit of knowledge. They have inspired me throughout my years. And while my father, who is a professor and a tech entrepreneur, would not qualify under my strict definition of garage inventor and garage entrepreneur for this dissertation, he has been a personal model for me throughout my life and I have thought about his professional experiences and career a lot as I developed the following work. The “garage” in this dissertation is a metaphor and his businesses in fact started in my grandparents’ converted cottage and the basement of the Buseck, Barger, Bleil, and Co. accounting building even. I

remember my mother going back to school to complete her Master's degree when I was a child. Together, they set me on this path and provided examples of academics before I even knew what I was learning from them. Similarly, I would like to thank my in-laws, Mary Ann and Robert Granahan. They have provided significant support to me and my family through this process which has helped to make this possible and it is greatly appreciated.

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For everyone I have missed, I thank you and look forward to saying so in person!

PREFACE

What if everyone could have one of these amazing machines in their own house? There's just one problem: They're as big as a house. The solution comes in, of all places, a garage in California. Young people with a passion for shaping the future put the power of the computer in everyone's hands. Together, we form a super network that glows with billions of interactions, and once again we stand on the brink of a new Renaissance.

… For the first time in history, all of us can have a say about the kind of world we want to live in. The choices we have made for the past 30,000 years have been inventing the future one day at a time. And now, it's your turn.

Spaceship Earth, EPCOT

A Garage and an Idea: What More Does an Entrepreneur Need?

Audia and Rider (2005)

Okay, well… probably a lot.

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LIST OF ABBREVIATIONS

HHI	Herfindahl–Hirschman Index
hr	Hazard Ratio
IAP	Inventor’s Assistance Program
IRR	Internal Rate of Return
MSA	Metropolitan Statistical Area
NBER	National Bureau of Economic Research
or	Odds Ratio
se	Standard Error
SMS	Simple Messaging Service
UIA	United Inventors Association
USPTO	United States Patent and Trademark Office
VSR	Variation–Selection–Retention

CHAPTER 1: INTRODUCTION

Where do new organizations come from and who is at risk of founding those organizations? These are two of the fundamental questions in organizational and entrepreneurship research (Aldrich and Ruef, 2006; Gartner, 1985; Krueger, 2002; Shane and Venkataraman, 2000). An enduring image in American culture is the heroic “garage inventor” turned entrepreneur (Audia and Rider, 2005; Cohen, 2011; Engber, 2013). This study, starting with the metaphorical garage, clearly identifies a set of individuals at risk of starting a firm in order to isolate and address the first question in the technological space, a phenomenon addressed as the “garage entrepreneur” for this study.

The garage has served as the setting for new entrepreneurs like such as Roy and Walt Disney leading to the Walt Disney Company, Ruth Handler who created the Barbie Doll and founded Mattel, Steve Jobs and Steve Wozniak of Apple, and Bill Hewlett and David Packard for Hewlett-Packard (Cohen, 2011). Hewlett and Packard’s story was so important that the garage they worked in is a designated historic landmark as the birthplace of Silicon Valley (Engber, 2013).

This dissertation studies the transition from independent invention to the start of new technological firms. In doing so, it investigates one of the first selection mechanisms along the evolutionary path from technological discovery to commercialization and market acceptance. Investigating the role of independent inventors in new firm formation, the research question is: *what factors at the potential founding time affect the likelihood of a garage inventor becoming a garage entrepreneur?*

In addressing the phenomenon, I will be investigating problems at the intersection of strategy, technology, and entrepreneurship. With respect to innovation, Teece (1986) highlights the difference between value creation and value capturing in technological innovation. Having overcome the challenge of creating a new technology, these inventors still face great obstacles in identifying means of protecting and profiting from their ideas (Gans, Hsu, and Stern, 2002). Prior research in technological venture formation frequently focus on knowledge sources for entrepreneurship that include firm spin-offs and employee entrepreneurship (Chatterji, 2009; Klepper, 2007; Klepper and Sleeper, 2005), university transfer (Katila and Shane, 2005; Shane, 2001a; Stuart and Ding, 2006), and user entrepreneurship (Shah and Tripsas, 2007; Tripsas, 2008). In each setting, the entrepreneur is able to overcome the complementary asset problem using different resources from his or her experience.

I am interested specifically in the perspective of the non-affiliated inventor(s) and the technology and context around them. Rather than from the perspective of the incumbent fearing disruption (Christensen, 1997), I explore the garage inventors and how the technological, social, and geographical environmental characteristics affect entrepreneurship. In doing so, I connect with recent research efforts that encourage investigation into the entrepreneurship processes not affiliated with firms or universities (Åstebro, 1998; e.g. independent inventors – Åstebro and Dahlin, 2005; 'Edisons or Hobbyists' – Dahlin, Taylor, and Fichman, 2004; 'user entrepreneurs' – Shah and Tripsas, 2007).

Utilizing a process model of entrepreneurship (Shane and Venkataraman, 2000), this study takes place after potentially recognizing an opportunity but before success or failure of commercialization. This space evaluates the inventor's decision to form a venture but not necessarily whether it is yet successful. In doing so, I am able to highlight a step in an evolutionary process for which inventors select themselves (or are selected) into entrepreneurship. This selection mechanism allows an insight into the options that are presented for later market selection.

In order to answer the question, I consider theories developed in other settings that resulted in entrepreneurial startups such as through university and firm spin-offs. While I draw from the logic that proved valuable in those settings, it is not immediately known if all the theories will hold in the same manner, and complement the theories with inventor independence. Independent inventors do not have access to the same resources or networks and may not develop technologies in line with those sources. I specifically develop hypotheses surrounding the nature of the technological, social, and geographical opportunity spaces in which the nascent entrepreneurs are operating.

CHAPTER 2: RESEARCH PHENOMENON

"Face it: Out there in some garage, an entrepreneur is forging a bullet with your company's name on it." – Gary Hamel (1999: 72)

The role of independent inventors and/or small firms have been debated in the literature (e.g. Amesse et al., 1991; Cohen, 2010; Fontana et al., 2012) for some time.

Classic Debates

Joseph Schumpeter is frequently seen as arguing on both sides and starting the debate of the importance of entrepreneurs and technological development, which is the engine of economic growth in his models. Schumpeter's gales of creative destruction are either primarily the realm of innovative entrepreneurs developing new technologies through radical new combinations of existing ideas and destabilizing the incumbents (Schumpeter, 1934) or are the product of the large R&D laboratories (Schumpeter, 1942) where large firms play a very important role. In economics, this argument has frequently been evaluated as determining the firm size (Cohen and Klepper, 1996b; Prusa and Schmitz Jr., 1991) or market structure that promotes innovation – i.e. do large monopolists have the incentive to innovate to avoid future competition (Cohen and Levin, 1989; Scherer and Ross, 1990)?

In the mid-twentieth century, scholars pick up the debate between inventors and large R&D labs again. In 1957, Jacob Schmookler addressed the prevailing idea that the inventor no longer has a place in innovation. He concluded that the large-scale enterprises are unquestionably contributing to technological progress but claiming that large R&D firms alone drive advancement is "entirely unwarranted" (Schmookler, 1957: 330). In his sample, 14% percent of the inventors assigned their patent to themselves or unassigned rather than a firm or the government. Additionally, he found that 7% of the inventions by technologists were "Not Part of [the] Job" (Schmookler, 1957: 332).

Jewkes, Sawer, and Stillerman (1971) similarly studied great inventions of the early twentieth century. In a study of sixty major inventions, half of them were invented by individual inventors without the support of research institutions. They evaluate that studies "continue to provide evidence of the important role of the independent inventor" (Jewkes et al., 1971: 205). They do however include university researchers in the independent category as long as the invention could clearly be linked to the efforts of the specific inventor and as long as the inventors were working autonomously, even within the university context. In more recent years, university spin-offs, that could have been some of those represented as independent in their sample, have received attention in academic literature (Foray and Lissoni, 2010; Jaffe, Fogarty, and Banks, 1998; Katila and Shane, 2005; Nerkar and Shane, 2003; Shane, 2001a). At the time of the Jewkes, Sawer, and Stillerman study, the rate of patenting amongst independent inventors had been declining. They acknowledge that the type of invention going forward may yet make laboratories and firms the source of invention, but conclude that it is still important to keep researching all avenues of such invention.

Recent Literature

More recently, Audia and Rider (2005) performed a study specifically on the image of the "garage entrepreneur." They conducted a random phone survey to test the popularity of the myth, finding that 87% of respondents could name at least one company started in a garage, basement, dorm room, or kitchen – where Apple and HP were the most likely responses. In a survey of 32 startups with VC funding in 2004, they found that 25% of the firms did start in garages, basements, dorm rooms, or kitchens. However, these were temporary locations early on and the authors highlighted that 91% of the companies were related to the founders' prior industry experience and prior social ties were important in 66% of the companies. They state that entrepreneurs are organizational products and feel that the image can be detrimental to individuals trying to become entrepreneurs by not emphasizing the social and knowledge source aspects and policy makers, business schools, and popular press should not highlight the phrase. Audia and Rider conclude that research on individual entrepreneurship should focus on identifying access to organizations, which can provide information on opportunities, role experience, social contacts, and access to key resources.

Other recent scholars have been calling for more studies in relation to independent inventors and innovation (e.g. Åstebro, 1998; Dahlin et al., 2004; Shah and Tripsas, 2007). Åstebro performed a survey of Canadian inventors who sought help from the Inventor's Assistance Program (IAP). With 1,095 responses, he was therefore able to study a sample of inventors with information at the time of IAP application as well as measures of performance from his independent survey. He reported the results in a series of articles.

Åstebro found that 6.5% of inventions by independent inventors reach the market, four-to-eight times less than inventions by established firms (Åstebro, 1998). However, he found that, conditional on commercialization, costs of development were about 1/8 those of other firms and they were able to obtain gross margins comparable to established firms. Specifically, of the 75 firms in his sample that reached commercialization, the average IRR was 11.4%. The returns were highly skewed though as six realized returns above 1400% and 60% obtained negative returns (Åstebro, 2003). He also noted that while 75% of the inventors were told by the IAP not to pursue their idea commercially, 50% of those continued working on it (Åstebro and Gerchak, 2001).

Evaluating the characteristics of success in his sample, Åstebro reported that of 36 characteristics of innovation, technology, and the market, four stand out as being related to eventual success: *expected profitability, technological opportunity, development risk,* and *appropriability conditions* (Åstebro, 2004). Clarifying further, *technological opportunity* is related to commercialization if the inventor believed his or her invention had high *technical performance* and low *technical uncertainty* (Åstebro and Dahlin, 2005). They suggest that the independent inventors applied for patents without taking into account commercialization considerations based on their survey results. Lastly, Åstebro and Dahlin find that the dominant mode (82%) of sales is through self-commercialization with the inventor involved. Regarding profitability expectations, the significant characteristics were *price required for profitability* and *anticipated stable demand* (Åstebro and Michela, 2005).

In a different study, Dahlin, Taylor, and Fichman (2004) took up the debate whether independent inventors were "future Edisons or weekend hobbyists." They sought to answer whether there was significant technical content and merit to encourage policy support of independent inventors. In the specific setting of tennis racket patents, they found that 65% of patents were held by independent inventors as compared to corporates and 59% of the independent inventors held multiple patents in the area. Analyzing the nature of independent inventions as compared to those developed by firms, the authors found that there is significant variation in the quality of inventions by independent inventors. They found that independent inventors are over-represented in both the most important and the least important pool of inventions in this category.

Singh and Fleming (2010) address the debate on the importance of variance in independent inventor outcomes as well, coming to different conclusions. Following literature that suggests variance is the important measure for creative outcomes (Fleming, 2001, 2007; Girotra, Terwiesch, and Ulrich, 2010), Singh and Fleming seek to test whether variance and mean performance are positively related in a large sample of patented inventions. Rather than suggesting that merely having variance is a good thing, they suggest that independent inventors will be more highly represented in the lower tail and less highly represented in the upper tail as compared to corporate inventors. They argue that corporate and team-based inventions will be better selected so as to eliminate poor outcomes prior to patenting. Additionally, corporate and team invention carry benefits such as access to a greater variety of knowledge to recombine – thus increasing the likelihood of creating breakthrough ideas. They supported this argument using quantile regression on over half a million patents that independent inventors are more likely to produce very poor outcomes and simultaneously less likely to create breakthroughs as compared to their corporate partners. They do not address entrepreneurship or commercialization but aim to enhance the debate on the (non-)importance of independent inventors based on their comparative inventive output.

In another study, Sirilli (1987) completed a study on over 500 inventors who filed patents under the Italian patent system in 1981. He found that 60% of the respondents were associated with a firm and the other 40% were "individual" inventors, although the population of patents from which his sample was drawn showed 51% of the patents had firm association in 1981 according to the Patent Office. Sirilli's main emphasis was on describing the background of the inventors in the sample and the incentives for invention. He found that nearly three-quarters of the inventors claimed their invention would have been developed even in the absence of the patenting institution. However, he still found patenting important and necessary for protecting their inventions.

Weick and Eakin (2005) repeat the call for more studies of independent inventors. In a short survey, they sought to investigate who these inventors are, measure the level and direction of their inventive activity, analyze how frequently these inventors take their products to market and in what manner, and test the correlations between sales achieved and market choices such as outright invention sale, start-ups, or licensing. Surveying individuals on the mailing list of the United Inventors Association (UIA) and the Inventors' Digest, they received 351 responses to a questionnaire on biographical and invention details, which represented a 9% response rate as measured over the total size of the mailing list. Most of their responses tended to work on hardware/tool, household products, industrial/commercial products, novelty items, and toys/games/hobbies. They found that 39% of their population generated some sales and 20% made a profit. In this sample, higher likelihood of achieving any sales was associated with starting their own business but a higher level of sales was associated with licensing rather than outright invention sale or starting their own business.

Lastly, a rising area of interest in the literature is highlighting *user entrepreneurship* (Chatterji and Fabrizio, 2014; von Hippel, 1988; Shah, Smith, and Reedy, 2012; Shah and Tripsas, 2007). From Shah and Tripsas (2007), the definition of user entrepreneurship is "the commercialization of a new product and/or service by an individual or group of individuals who are also users of that product and/or service" (Shah and Tripsas, 2007: 124). They further segment this into two categories: professional-users and end-users. In this definition, it is not strictly restricted to individuals outside of work or research relationships. The area significantly overlaps, especially with end-users or consumer goods and sports products, which has been tested under the user entrepreneurship model (Fauchart and Gruber, 2011; Shah, 2005). However it also includes physicians using medical devices and providing their feedback to the manufacturers (Chatterji and Fabrizio, 2012). Shah and Tripsas (2007: 123–124) specifically call for increasing the study of entrepreneurship out of the regular contexts of firm and university spin-offs which leads them to the area of demand-use and user entrepreneurship. I repeat the call for study outside of university, firms, or other organizations but suggest that the alternative category is broadly independent invention. I then do not yet assume characteristics of the motivations of the inventors and entrepreneurs but define the scope of this study based on their working relationship, primarily through a clear patenting relationship with an existing organization prior to the inventor become independent.

To wrap up the question of significance, a recent study on the acquisition and commercialization of invention suggests that 49% of manufacturing firms that innovated during 2007 – 2009 did so with a product that originated outside the focal institution, namely through customers, suppliers, and "technology specialists" that included independent inventors (Arora, Cohen, and Walsh, 2014). They found that while customers were the most frequent source of such inventions, technology specialists provided inventions that were more economically valuable.

Garage Inventor to Garage Entrepreneur

For this study, I use two terms that define the context and constructs – a garage inventor and a garage entrepreneur. **A "garage inventor" is an individual or individuals whose technological product or process, embodied in their first patent, is developed**

outside the context of a firm, university, government, or other formal organization. Specifically, the inventors own the technologies themselves rather than assigning it to another organizational entity. It is important to note that this definition does not include all independent inventors where a technology is not assigned to an organization. The "garage" status of an inventor is defined at the time of his or her first patent. Inventors who first develop technologies for an existing firm may later have independent (i.e. non-assigned) patents but they will not be considered "garage" under this definition. Additionally, this status is limited to independence of an organizational affiliation but *not limited* by "lone wolf" inventive status where the inventor does not work with anyone in the invention stages. In fact, the co-inventing relationships will prove to be important substitutes for working relationships. **A "garage entrepreneur" is the garage inventor who subsequently starts a new technological firm after such invention**. A garage entrepreneur will therefore be a subset of garage inventors for this context. This differentiates from inventor/entrepreneurs associated with other new technological entities in the patent database. To test knowledge use and development for garage entrepreneurship, I focus solely on the venture formation conditional on having developed a new technology. This results in the study highlighting this type of technological entrepreneurship where technologies were not spun out from previous entities. See Figure 1 for an evolutionary model of the Garage Entrepreneurship that I study.

In this model, the technological development occurs as variations in the environment. Each variation is an opportunity for a new firm but the specifics of the invention process is outside of the scope of this dissertation. Conditional on invention, the garage inventor then patents the technology having identified the possible opportunity. Then, different factors will affect the process after opportunity identification as the inventor decides to form a new venture or not in order to capitalize on the invention. Following this decision, the market acts as the retention mechanism and provides feedback whether the firm should continue to exist and how successful it will be. This leads to evaluating the selection mechanisms that expand the technological variations into entrepreneurial ventures.

Primarily, I am investigating the difference between the inventors who turned into entrepreneurs and those who did not. I develop the dataset initially from the USPTO patent grants to non-affiliated inventors. For example, during 1980 – 2009, on average 15% of total patents are non-assigned.

CHAPTER 3: THEORY AND HYPOTHESIS DEVELOPMENT

Entrepreneurship is based on identification and exploitation of opportunities (Shane and Venkataraman, 2000). The discovery or creation of a new technology creates the opportunity. Given the model under evaluation, the inventor has shown awareness of the opportunity but different factors can increase the awareness of market value and potential opportunity (Kirzner, 1973) or otherwise prompt the inventor to action in attempting to commercialize the technology (Mollick, 2012).

To answer the question of what factors prompts the garage inventor to become a garage entrepreneur (Amit, Glosten, and Muller, 1993), I first investigate characteristics of the social environment in which the potential entrepreneurs are embedded. I then develop arguments on the product and competitive environment at the time of the invention.

Social Opportunity Space

The types of resources a potential entrepreneur brings can be critical for firm survival and long-term success (Alvarez and Busenitz, 2001; Kerr, Kerr, and Nanda, 2015). Besides physical resources, the sociological foundations of entrepreneurship highlight the people, networks and institutional environment to which nascent entrepreneurs have access as critical drivers of action and ultimate success (Aldrich and Ruef, 2006; Nanda and Sørensen, 2010; Thornton, 1999). One of the important elements of networks is access to technical and market knowledge and experience. It is important to note that in this context, independent invention does not mean that the inventor is working alone or has never worked with other individuals. For this study, independent invention means that the inventor or inventors developed the technology outside of a work relationship with a firm, university or other organization that can claim ownership over the focal technology.

The focal invention is developed outside of these affiliations. However, it can be developed by a team or by individuals who have worked in teams prior to the focal independent technology. Leveraging knowledge gained from prior affiliations can help them overcome tacitness of external knowledge (Kogut and Zander, 1993), a valuable condition as most knowledge will be outside of the individual inventor without a formal affiliation. The knowledge required for successful innovations that are more likely to be radical and valuable as described above can therefore come from the size of the network even if not directly from the focal technology. For technologies actually developed by multiple inventors, each inventor can have unique knowledge and experiences (Gruber, MacMillan, and Thompson, 2013; Haas and Hansen, 2007).

If the inventors are strongly linked, the inventors will have access to nearly the same knowledge (Granovetter, 1973) and the invention could be limited in its value. However, if the inventors have different networks, one new path can open access to very different new knowledge that can be turned into value. As knowledge from different areas are recombined together, the likelihood of success increases. Focusing on more than just the size of the network, garage entrepreneurs will have networks of co-inventors with a variety of knowledge expertise. As the number of inventors increase, the likelihood of having new knowledge increases (Jones, 2009). Therefore, I hypothesize the positive effects of the size of the inventive network:

Hypothesis 1: Garage inventors are ***more likely*** *to become garage entrepreneurs as they* ***are professionally connected to more inventors****.*

Technological Opportunity Space

"I fear someone in a garage who is devising something completely new."

Bill Gates (1998: as described by Grossman, 2012) in response to a question as to which competitor he feared most.

The innovative process is frequently seen as recombining prior knowledge in order to achieve novel combinations (Schumpeter, 1934; Spender and Grant, 1996). Incumbent firms are more likely to start working on process innovations (Cohen and Klepper, 1992, 1996a) and produce technological innovations that are very similar to their existing technologies (Helfat, 1994). Opportunities can also exist when actors specifically hold different views on the value of the technology. Even if incumbents were aware of a potential technological opportunity, they may not pursue it because they do not understand the importance of the technology – which will be more difficult as the technology becomes more radical and harder to evaluate – or that it is not economically important for them.

New technological categories are likely to emerge from new and small firms (Prusa and Schmitz Jr., 1991). Partially, this could be a function of the selection mechanism by inventor/entrepreneurs. Regardless of the technologies the independent inventors actually create, they are more likely to evaluate the opportunity as important if the idea is radical and potentially significant (Gans et al., 2002). If the idea is simple, inventors may recognize some small value but will not pursue the technology commercially. Additionally, incremental innovations that are not radical are more likely to be tied to existing technologies that are controlled by the existing incumbent firms. This will discourage inventors either cognitively as they evaluate the opportunity or rationally as they understand that the complementary products are not under their control and they will have a difficult time selling the enhancement. Entrepreneurs are also more likely to commercialize inventions themselves as the scope of the patents increases (Nerkar and Shane, 2007; Shane, 2001a). Under conditions of broad technological application, the opportunities will increase as the inventor can see markets in different areas (Shane, 2000) that the technology can be applied. Altogether, these arguments suggest that radicalness and significance of the technology will increase the rate of entrepreneurship amongst garage inventors.

Small, entrepreneurial firms, especially those started by independent inventors, will not have significant amounts of excess resources in order to compete broadly. They are best able to enter when small, niche market opportunities are available (Gans and Stern, 2003; Katila and Shane, 2005). By targeting niche markets, the independent inventors will be able to gain experience and perfect their products while not experiencing the full competitive pressures (Christensen, 1997). As the availability of niche markets increase, even if incumbent firms identify the opportunity, they may not see the profitability compared to their existing market (Bhide, 1992; Christensen and Bower, 1996). As the market concentration increases, existing firms will be more competitive and likely to respond to external events (Turner, Mitchell, and Bettis, 2010). With such concentration, independent firms may not be able to identify the market opportunities for smaller technological products.

Higher fragmentation creates more ambiguity in the market, an area where startups can maneuver to find a competitive position. Market segmentation is related to customers' willingness for differentiation (Shane, 2001b). Some technologies will allow different attributes to be highlighted from different firms. In established technological industries, firms will follow the product characteristics valued by their large customers, allowing the possibility for niches to exist for small firms (Christensen, 1997).

These niches may exist as a large number of competitors are present in the environment (Katila and Shane, 2005) and similarly when the industry concentration is small (Nerkar and Shane, 2003). Niches are particularly relevant as incumbents are not able to serve the fringe users and new companies can test their products with little direct competition (Malerba et al., 2007). Therefore, I hypothesize that the presence of market niches, or areas of less competition for inventors, will be related to inventors starting new ventures to commercialize their inventions.

Hypothesis 2: Garage inventors are ***less likely*** *to become garage entrepreneurs as the* ***competition*** *in the* ***technological space increases****.*

Geographical Opportunity Space

Another sociological factor includes the startup activity in the area (Konczal, 2013). As the amount of startup activity in the area increases, entrepreneurship is more likely to be visible as their friends or colleagues start to engage in entrepreneurship (Kacperczyk, 2013; Roach and Sauermann, 2015). With increased startup activity, specialized resources dedicated to supporting such activity could increase which will allow for easier access by other potential startups.

With a large amount of entrepreneurship in an area, it is also more likely that the inventor is connected with someone who has entrepreneurial experience. This connection will help encourage entrepreneurship as connections will demonstrate to the inventor that starting his or her own business is an option for the technology (Roach and Sauermann, 2015). These connections can serve to evaluate the ideas for entrepreneurial potential and directly connect the inventor with other necessary resources.

Even without the direct connection, a wave of entrepreneurship in the area can equally serve to encourage the inventor to consider firm formation (Freeman, 1986; Thornton, 1999). This has been seen similarly in acquisition waves (Stearns and Allan, 1996; Thornton, 1995). The startup activity and social pressures can serve to promote entrepreneurship regardless of the actual quality difference in the invention. Therefore, I suggest that startup activity will increasingly promote entrepreneurship from the set of garage inventors.

Hypothesis 3: Garage inventors are ***more likely*** *to become garage entrepreneurs as* ***incidence of entrepreneurship in their geographical area increases****.*

Experience

Entrepreneurial opportunities exist when the existing actors having different ideas of the potential value of an opportunity (Kirzner, 1973), are cognitively not able to recognize the opportunities, possibly because of their existing knowledge structure (Shane, 2000), or when the opportunities are created by luck or foresight through the recombination of previous ideas (Schumpeter, 1934).

Social and organizational connections serve to cull ideas earlier (Singh and Fleming, 2010) and provide feedback as new ideas develop. Without such connections, the alternative is for the inventor to develop the ideas and obtain feedback once new technologies are developed. This process of experiential learning increases the skill at patenting good technologies, claiming the required technological area to allow the inventor to commercialize it later. The feedback also improves the product that the inventor is providing before the inventor makes the decision to start a new firm with his existing technological portfolio.

Further, organizations are repositories of technologies, associated resources, and stored and tacit knowledge accumulated over time related to their technological portfolio (Spender and Grant, 1996). A single independent patent defines the start of a technological trajectory but the inventor will need a fuller portfolio in order to increase their confidence of survival and economic viability (Somaya, 2012). Therefore, as an inventor both improves on the technology and builds a thicket of patents more capable of protecting the technological area, thereby increasing expected economic returns, the inventor is more likely to engage in entrepreneurship:

Hypothesis 4: Garage inventors are ***more likely*** *to become garage entrepreneurs as their* ***inventive experience increases****.*

CHAPTER 4: DATA AND METHODOLOGY

In order to study the phenomenon of technological entrepreneurship by garage inventors, I study the transition from inventor to entrepreneur by operationalizing a garage inventor as an inventor in the patent database whose first patent is independently owned by the focal inventor and he or she has no recorded working history with an existing organization from the patent database. This is likely to capture those firms that have the potential to be vibrant additions to the economy. Patents have been shown as valuable resources for entrepreneurial companies (Hsu and Ziedonis, 2013) and as able to increase likelihood of receiving venture capital funding (Hsu, 2006; Stuart, Hoang, and Hybels, 1999).

Sample and Data

Using the Harvard Patent Dataverse (Lai et al., 2013) from 1980 to 2010, I identify the individuals who develop their first patent without an organizational assignee. This data is useful as it was designed to disambiguate inventors specifically to enable the study of inventor mobility in the database (Marx, Strumsky, and Fleming, 2009) which is similar to identifying the transition from independent inventor to entrepreneur. Figure 2 represents the trend of independent inventors patenting within the USPTO during a sample of the time under analysis for this dissertation.

Since the goal of my study is to understand the entrepreneurship founding process, use of a longitudinal panel could create an issue of sampling on the dependent variable, leading to issues with the validity of the results. As such, I follow the studies of Ahuja and

Lampert (2001) and Nerkar and Paruchuri (2005) by following the entire cohort using a hazard model to allow censoring in yearly spells.

Censoring in this case represents right censored data whereby the entry is known but the exact exit point for the inventor is unknown. Once an inventor becomes an entrepreneur, the exit event is clear. Alternatively, I remove inventors after 20 years from the date of their last patent. After such a time, I have reasonable confidence that they are unlikely to start a firm based on the technology. Not only has a significant amount of time passed but per the legal timeline of the patent grant, their patent has expired. If the technology had value, the inventor no longer has an exclusivity right. While the model could be run as true continuous time, the yearly spells allow for updating the independent variables that vary with time for the inventor. Therefore, any year that ends with no known entrepreneurship event, the inventor is said to be right-censored. The inventor is therefore still in the analysis but the research methodology then allows me to empirically deal with their presence but unknown outcome. This is therefore different from clearly saying that inventor *has not* founded a firm. Censoring allows for such a distinction empirically.

I follow patenting inventors without corporate pre-history who applied for at least one granted patent after 1980. With a patenting pre-history to 1975, I can examine their background and history as well as have a robust timeline to follow their future career. This results in an initial risk-set of just under 190,000 technologies by nearly 225,000 unique garage inventors in the United States, which could be used to form a new venture. I develop the method to track the garage inventors and their subsequent patents to understand which were later owned by a new venture. Table 1 presents high-level statistics representing the patent database and garage inventor.

The Appendix highlights the part of the process of evaluating firms as brand new entities and providing secondary verification on their founding. After initially matching the data the first-level identification strategy described above, I had a sample of 7,732 new firms in the USPTO data associated with inventors whose first patent had been unassigned to any organization. I went through the list to eliminate assignments that did not match the idea of a new, entrepreneurial firm. Namely, many were assigned to another inventor, especially when multiple inventors were on the patent but it would be owned by one in particular. Some universities' first patents were present in this sample and were thus eliminated. Foundations, trusts, institutes, and government organizations were removed if they were one of the new patenting organizations. Some international companies with GmbH (Germany) or SpA (Italian) with American inventors were also present and therefore removed. After this process, I was left with 5,780 firms. In the final analysis that relies on full data availability, I have a complete sample of 5,684 new firms in the patent database and 152,092 unique garage inventors.

Without controlling for any characteristics, the cumulative firm foundation percentage is presented in Figure 3. The percentage is scaled based on the inventors in the data set that *do* start an entrepreneurial firm, not on the total population of inventors. If scaled to the entire garage inventor list, the figure would asymptote to about 4%. From the figure, we can see that 20% of inventors who start a new firm will do so in the same year as their initial parent. Within five years after the garage patent, 85% of those who will become entrepreneurs have done so. While I will eventually discount inventors who become entrepreneurs after 20 years, the figure also demonstrates that it is just under 100% of the future founding entrepreneurs at the expiration of their initial patent.

Model Specification

I used a Cox Proportional Hazard Model of the form:

$$h_i(t) = \lambda_0(t)\exp\{\beta_1 x_{i1} + \cdots + \beta_k x_{ik}\}$$

where the baseline hazard function is left unspecified and the results are relative to this unknown and unspecified function. Between two individuals, the ratio of hazards is then:

$$\frac{h_i(t)}{h_j(t)} = \exp\{\beta_1(x_{i1} - x_{j1}) + \cdots + \beta_k(x_{ik} - x_{jk})\}$$

Further the $\lambda_0(t)$ cancels out in the ratio. The analysis then tests a set of covariates on the risk of an event happening – the garage inventor engaging in entrepreneurship by patenting under a new technological entity.

The data is structured as survival analysis with a yearly outcome. I follow every inventor who applied for a patent 1980 onward under the proposed garage status in this study. In each year, I can specify their likelihood of patenting with a new technological entity, whether or not they patent in the following year. This also allows us to incorporate censoring for non-patenting in the outcome year.

Independent variables are defined by the characteristics of the inventor, the patent, or the environment in the year prior to the dependent variable. For yearly changing of independent variables, the outcome variable is always measured the year after the independent variable. This lag separates the characteristics of the technological area as an input from the output characteristics. I do not reset the inventor's status mid-year to allow multiple positive outcomes in a year (i.e., if the inventor files for a garage entrepreneurial patent in January and November of 2000, the outcome would still be one for positively patenting under a garage entity in 2000). While there are some repeat garage entrepreneurs, I remove them from the analysis once they become an entrepreneur. Alternatively, they are removed from the analysis 20 years after their last active patent has been filed. This is the length of patent validity and thus highly unlikely that they would rejoin the analysis with any characteristics resembling the expired patent. A simplification of the structure of the data used in the survival model is presented in Figure 4.

Dependent Variable

Garage Entrepreneurship: The dependent variable denotes whether the garage entrepreneur patents with a new technological entity in the focal year. A new technological entity is the first occurrence of the assignee in the Harvard Patent Dataverse (Lai et al., 2013) as defined by the *asgnum* indicator which incorporates the NBER (Hall, Jaffe, and Trajtenberg, 2001) *pdpass* into their own fuzzy string algorithm for disambiguation. This is similar to a definition used by Malerba and Orsenigo (1999) broadly on technological entry in new classes in the European patent data but is being applied to the first patent ever by a firm. Only the very first patent instance of the assignee is considered the entrepreneurial event and I consider any inventor on that patent to be the entrepreneur on record. If the garage inventor is associated with such a patent, then the dependent variable in the hazard model is triggered. All other outcomes including non-patenting, filing another independent patent, or filing a patent under an existing organization are considered censored events. No characteristics of the entrepreneurial patent are used for the analysis other than its presence or absence and independent variables are not updated when the patent is developed.

Independent Variables

For all variables, independent and dependent, patents were classified as occurring in the application year of the patent when determining the timing and characteristics for each variable.

Number of Inventors: The first independent variable is the number of inventors on the patent under analysis. The "garage" status is defined at an inventor level while each patent may have multiple inventors and the analysis is done at the inventor level. Once an inventor has a patent, this is a time-invariant characteristic in the hazard model until the inventor develops a further patent. If the inventor develops a further patent, the characteristic is immediately updated on the basis of his most recent patent and is used going forward. If more than one inventor has "garage status" on the patent, then the first listed inventor is used.

Other Unique Inventor Ties: This variable is the number of unique inventors directly connected to the team of inventors prior to the patent under analysis. For a patent with one inventor, this represents the total number of other inventors he has worked with prior to this event. For a patent with a team of inventors, this is the cumulative unique inventors, separate from the focal team, that are connected to the inventors on this patent. Together with *Number of Inventors*, these variables represent a first and second degree strong social connection through which knowledge and information can be transferred. This variable is only updated with the generation of further patents with different network ties.

Inventor Experience**:** Experience is measured in the cumulative number of successful patent applications by the focal inventor. This is automatically set as the value from the previous year until a new patent is developed, at which time the variable is updated through the end of the current observation spell. This value is transformed for the model as *ln(experience)*.

Firm Herfindahl: To operationalize the concentration in the technological opportunity space, I utilize the Herfindahl index (HHI) of firm patent ownership in the primary patent technological class. The Herfindahl index was originally used to calculate market share for competition and antitrust law but has also been used for technology management. I create the Herfindahl index by examining the 'market share' of the different assignees in the technological space in a given year. A higher Herfindahl index would suggest that a few firms are dominant in the technological area. For this analysis, I multiply the traditional calculation by ten in order to scale the variable from 0 to 10 to have a finer understanding of the concentration, especially for interpreting results. The calculation for HHI is:

$$HHI_{it} = \sum_{j=1}^{J} \left(\frac{n_{ijt}}{N}\right)^2 * 10,$$

where *i* is the primary technological class and *j* is each existing organization that patented in that technological area in year *t*; *n* is the number of patents assigned to the organization and *N* is the total number of patents.

Independent Inventors in Technological Area: The complement of current competition in the technological area is the potential competition in the technological area. Especially from the perspective of a current independent inventor evaluating the technological opportunity, the inventor can determine how many potential entrants there are by the number of patents assigned to independent inventors – those that are similar to him have the potential to become an entrant. This variable is measured as the log transformed number of independent patents in the technological area in the previous year.

Previous Affiliation: The dummy variable where one in *previous affiliation* recognizes whether an inventor has, at that point in time, ever patented with an existing organization and zero represents never having been affiliated with an organization up to the analysis time. Every inventor under this analysis started his or her patenting career independent of any organization. However, it is possible for garage inventors to join an existing organization prior to becoming an entrepreneur. This dummy captures the transition to employee that may bring resources that non-affiliated inventors still do not have.

Size of Previous Affiliations: To further understand the significance of any prior organizational affiliations, this variable measures the maximum size of any prior organizational affiliation as calculated by the log of the number of patents owned by the organization at the time of inventor affiliation. Once an inventor works with a corporate affiliation, this becomes a stable characteristic of the inventor for all future observation spells. Depending on which regression model, this is valued at zero if the inventor has no prior organizational affiliation or is left out of the model as blank when evaluating organizational affiliation separate from the whole sample.

Venture Capital Deals in the State: One defining characteristic of the geographical opportunity space is the potential for outside funding which is a significant indicator for technological firms in particular (Hsu and Ziedonis, 2013; Stuart et al., 1999). The data is collected by the National Venture Capital Association (Franklin and Taylor, 2015) and Thomson Reuters that records the information and makes it available in their *Stats and Studies* Yearbook. This variable is the log of the total number of venture capital deals in the inventor's state in the focal year.

MSA Entry Rate: Further representing the geographical area, the Census Business Dynamics Statistics (US Census Bureau Center for Economic Studies, 2015) allows measurement of aggregated business dynamics information on a yearly basis built from the confidential Longitudinal Business Database. The entry rate is measured at the Metropolitan Statistical Area (MSA) and provided by the BDS. It is originally calculated as 100 * (number establishments entering in the year divided by the average number of establishments in the MSA).

MSA Exit Rate: The *exit rate* is determined in the same way as the *entry rate* but is measured as 100 * (the number of establishments that exited the area divided by the average number in existence in the year). Research highlights the opportunity for new firm development based on the closing of existing firms, unintentionally allowing existing firms to spin off their knowledge as entrepreneurial firms (Carnahan, 2013; Hoetker and Agarwal, 2007).

Time Since Invention: This variable is measured in years since the inventor's last patent. The Hazard Model tests the age of the patent and this time-based likelihood of engaging in technological entrepreneurship.

Controls

Additionally, I control for a few additional characteristics that are related to the independent variables or are theoretically relevant to the experience of the inventors:

Claims: This is the log of the number of claims on the patent. Claims has been used as a proxy for the significance of the technology and is correlated with the economic value (Nerkar and Paruchuri, 2005; Tong and Frame, 1994).

Five-year Citations: Both as a possible measure of significance and as a feedback mechanism, I include a rolling five-year citation rate indicating the total number of citations in the last five years that the inventor's patents have received prior to the focal year. This measure proxies for technological significance (Ahuja and Lampert, 2001) and offers the inventor feedback as to how and in what way other entities are using the inventor's technology.

Originality: The *originality* is a characteristic of the technology defined by the nature of the references on the patent (Hall et al., 2001) which represents the concentration of technological classes in the backward citations of the patent:

$$Originality_i = 1 - \sum_{j}^{n_i} s_{ij}^2,$$

where s_{ij} denotes the percentage of citations made by patent *i* that belong to class *j*. This is similar to the Herfindahl index and describes how broadly this technology connects to different technological areas. This is a time-invariant characteristic but is updated if the inventor develops a further patent.

Backward Citations: The number of backward citations is a relevant control with the *originality* measure and is another indicator of the amount of knowledge recombined in the focal technology (Fleming, 2001). This is a time-invariant characteristic but is updated if the inventor develops a further patent.

Male: The gender of the inventor is determined by matching the inventor name and year to the Social Security Administration data on social security applications in each year. (Social Security Administration, 2014). Patenting is predominantly performed by males (Hunt et al., 2013) and gender may affect the decision to engage in entrepreneurship following the invention and patenting (Delmar and Davidsson, 2000; Kuppuswamy and Mollick, 2015).

New Firms in Database: The nature of new startup firms may have a time-varying nature specific to technological firms and the patent database. The *log of (1+number of new firms in the entire patent database)* in that year is included as a control for the market trends in entrepreneurship in general and the manner in which such firms were started in the patent database. This measures the number of new firms regardless of inventor garage status or whether those firms were directly measured as an outcome for this study.

Lawyer: As a proxy for resources, the *lawyer* variable is a dummy indicating whether the inventor utilized a lawyer to file the patent. This expense is not strictly required and the lawyer information is included on the patent. This data is available for all patent grants from 1998 onward and is from the Harvard Patent Dataverse (Lai et al., 2013).

Zillow Estimate of Home Value: Lastly, as another proxy for resources available to the potential entrepreneur (Jensen, Leth-Petersen, and Nanda, 2015; Kerr et al., 2015), the estimate of the inventor's personal home was collected using the inventor address and the website Zillow.com which proceeds home value estimates as well as general market conditions over time (Zillow.com, 2015). Home values for the set of garage inventors who started their careers in 2005 were collected and the value of the house fluctuated on the basis of local conditions in the zip code of the inventor.

CHAPTER 5: RESULTS

The main summary statistics are presented in Table 2. The correlations are presented in Table 3 and Table 4. The variables presented below are the primary independent variables. Most count variables will be logged due to the skewness present in their distributions.

Summary Statistics

A second set of summary statistics is presented in Table 5 that presents the summary statistics based on entrepreneurship condition. Part of this study is to document and explore the entrepreneurial activity in the patenting database in general related to garage inventorship. Table 6 and Figure 5 through Figure 8 help visualize the location of garage inventors and entrepreneurs representing the total number of inventors or entrepreneurs, respectively, in the state between 1980 and 2009 or the number weighted by the average population of the state during this timeframe. Again, garage inventors are counted if their first patent in the USPTO database is independent of an assignee organization. The garage entrepreneur data is based on the definition within this dissertation of the subset of garage entrepreneurs who subsequently produce the first patent for a brand new assignee within the USPTO data. California, New York, Florida, and Texas are the most prominent areas by raw number of both inventors and entrepreneurs. When weighted by population, New York, Virginia, Massachusetts, New Jersey, Alabama, and North Carolina are the top six inventorship areas with a rate above 2,000 garage inventors per million residents. Finally, New York, Virginia, Massachusetts, and New Jersey, all have a rate of garage entrepreneurs above 150 per million residents; and North Carolina, Wisconsin, Alabama, Arizona, Utah and Mississippi all have a rate of garage entrepreneurs above 50 per million residents.

Main Results

The Cox Proportional Hazard Model is a continuous time model that relates how the risk of an event – in this case, the patenting under a new technological entity – to the underlying hazard function (Allison, 1995). Hazard rates relative to the baseline are presented. To obtain the coefficients on the variables, calculate the natural log of the hazard rate (i.e., for Inventor Experience in Model 1, the coefficient would be ln(2.068) = 0.727). This is a proportional hazard rate where a value above 1.0 represents an increased likelihood of the event occurring and a value below 1.0 represents a decreased likelihood of the event happening.

Table 7 presents the results of the Cox Hazard Models with Model 1 representing the full analysis period from 1980–2009. I present the asterisks for reference but the tables also contain standard errors to help further understand significance levels (Bettis et al., 2016).

The *Number of Inventors* is positive with an odds ratio of 1.194 *(se = 0.008, $p < 0.001$)*. As the number of inventors on the garage patent increases by 1, the likelihood of the garage inventor becoming an entrepreneur increases by 19.4%. Similarly, as the *Prior Unique Ties of Inventors* increases, the likelihood of becoming an entrepreneur increases by 15.7% *(hazard ratio = 1.157, se = 0.009, $p < 0.001$)*. Together, these highlight the positive effect of strong network ties in the social opportunity space, either through direct co-invention in the previous patent or indirect connections by the focal inventor's prior patenting history or the second-degree connections brought by the co-inventor.

With regard to the technological opportunity space, the effects of current and potential competitors is most obviously noticed. The *Herfindahl concentration* is negative with a reduction in likelihood of just over 30% for a one unit change in the concentration in this industry. The Herfindahl index, usually presented from 0 to 1 was rescaled from 0 to 10 to highlight the gradations. Therefore, a unit change is equal to a 10% increase in concentration, reducing the likelihood of entry by a significant amount *(hr = 0.692, se = 0.038, p<0.001)*. This represents the current competitive landscape in the technological space. Alternatively, garage inventors could look at the area and determine the potential competitors by including the number of garage inventors in their evaluation of the technological space. The *log of the number of independent inventors in the technological space* is negative and significant *(hr = 0.890, se = 0.014, p<0.001)*. As the number of potential entrants as independent inventors increases by one standard deviation, the likelihood of entrepreneurship reduces by 11%.

Next, I evaluate the results for the opportunity space as defined by the inventor's geography. As the number of *venture capital deals* in the inventor's state increases by one standard deviation, the likelihood of the inventor generating an entrepreneurial patent increases by 3.5% *(hr = 1.035, se = 0.009, p<0.001)*. This is not a direct measure of capital infusion to businesses but a proxy for financial capital that could be available in the area and interest in technological startups. This still shows a positive effect of the amount of interest in technology businesses around the entrepreneur. Next, as the rate of *entry of new establishments* in the inventor's MSA increases, the inventor is likely to become an entrepreneur with an increased risk of 2.4% *(hr = 1.024, se = 0.008, p = 0.003)*. The *exit rate of establishments* in the inventor's MSA however is not significant *(hr = 0.987,* *se=0.012, p=0.309)*, suggesting that the entrepreneurial event is not driven by the closing of existing local establishments. This dichotomy in particular highlights the positive benefits of entrepreneurial growth in the area of the inventor.

Next, I discuss the results of increase in experience for the garage inventors. Each inventor under analysis begins with a single patent and no previous organizational affiliations. As the inventor patents more technologies, they are significantly more likely to become entrepreneurs at a rate of 108% *(hr = 2.068, se = 0.056, p < 0.001)* as they increase their patent portfolio by one standard deviation. Next, if the focal inventors joins an existing firm, they are also more likely to spin back out and become an entrepreneur with an increased hazard of 94% *(hr = 1.936, se = 0.112, p < 0.001)*. The characteristic of this process is also started to be tested as the size of the organization's patent store. Namely, as the number of patents owned by the organization increased by one standard deviation, the likelihood of becoming a garage entrepreneur decreases by 24% *(hr = 0.763, se = 0.010, p < 0.001)*. Lastly, the time since invention is negative with a hazard ratio of 0.935 *(se = 0.004, p < 0.001)*. The likelihood of becoming an entrepreneur decreases with time, which matches the raw pattern seen in Figure 3.

Finally, I will discuss the control variables presented in the model. The first set control for various patent-level characteristics. The *log of the number of claims* on the patent increases the likelihood of the inventor generating an entrepreneurial patent by 37% *(hr = 1.367, se = 0.023, p<0.001).* The five-year citation rate of the garage patent does not significantly affect the entrepreneurial rate *(hr = 0.999, se = 0.003, p = 0.812)*. However, the originality score does increase the likelihood of become an entrepreneur by 27% *(hr = 1.270, se = 0.063, p < 0.001)*. Each additional backward citation included in the original patent also slightly increases the likelihood of the inventor becoming an entrepreneur *(hr = 1.003, se = 0.001, p < 0.001)*. Even despite the majority of patentees being male to begin with (91%), males were 119% more likely to move forward toward entrepreneurship *(hr=2.185, se=0.137, p<0.001)* than females in this population. Lastly, the presence of new firms in the patent database in that year, representing further patenting and entrepreneurial activity in the times, also significantly increases the likelihood of the inventor producing an entrepreneurial patent by an increase of 198% *(hr = 2.975, se = 0.266, p < 0.001)* with a one standard deviation increase in the number of new firms in the year.

Note that about 4% of the subjects within this analysis become entrepreneurs (5,684 garage entrepreneurs out of the 152,092 garage inventors included in Model 1). This rate differs from the overall statistics presented in Table 1 based on the availability of data for the full model and decisions to cull as described in the methodology section.

Subsample Analyses

I run four more models to elaborate on the results of Model 1. Specifically, next I break out the analysis as Table 8 into Model 2 and Model 3, which separates inventors who, respectively, never become affiliated with an existing firm prior to their final results from those who do join an existing firm. Model 2 presents the analysis for the garage inventors who do not join an existing firm. The outcome is either an entrepreneurial event, triggering a 1 in the dependent variable, or censored, triggering a zero. Model 3 is for the subset of garage inventors who will join an existing firm at some point prior to their removal from the analysis. The majority of garage inventors (93%) do not join an existing firm as they develop patenting experience.

Model 2 mirrors the effects in model 1 but excludes the firm affiliation variables. Directionally, all the main effects operate in the same predicted manner. The main results are slightly more pronounced without those that will join a firm. For example, there is a slight increase in the importance of the inventor connections, a hazard ratio of 1.265 as compared to 1.194 previously, and inventor experience. A new co-inventor on the focal patent now increases the hazard to 1.265 *($se = 0.006$, $p < 0.001$)*. If one co-inventor is added, the likelihood of the non-affiliated inventors to become an entrepreneur increases by nearly 27% as compared to 19% in the full model. Similarly, a prior outside connection to the patenting team increases the likelihood of a garage inventor becoming a garage entrepreneur by 20% *($hr = 1.202$, $se = 0.009$, $p < 0.001$)* rather than 15.7% from Model 1. These effects start to indicate the effects of the corporate affiliation in the other sample. The importance of inventive experience is slightly enhanced with a 120% benefit *($hr = 2.196$, $se = 0.070$, $p < 0.001$)* while it was still a very strong 107% increase in the base model.

Model 3 is the subset of inventors who will become affiliated with an existing organization during their patenting career. This represents about 7% of the garage inventors from the initial sample. The main effect is that corporate affiliation after a garage invention but before the entrepreneurial decision mutes many of the other hypothesized effects. The number of inventors is now negative *($hr=0.952$, $se=0.021$, $p = 0.022$)*, reducing the likelihood of becoming an entrepreneur by 5% as a direct co-inventor tie is added rather than the 19% positive effect in model 1. Other second order ties is still positive but at a rate of 4.2% increase *($hr = 1.042$, $se = 0.020$, $p = 0.033$)* rather than the initial results of 16%. The technological competition space is no longer significant as measured by firm concentration or number of independent inventors in the area but still negative for the Herfindahl *($hr = 0.835$,* *se = 0.117, p = 0,198)*. The total number of other independent inventors in the technological space is positive but with a 95% confidence interval that would range from 0.957 to 1.097. Finally, inventor experience is still positive with a 65% *(hr = 1.648, se = 0.112, p<0.001)* rather than 116% in the full model. For this model, I also highlight the size of the affiliation. As the firm size *decreases*, measured by the log of the number of patents at the time of affiliation, the more likely the initial garage inventor is likely to later become an entrepreneur by nearly 9% *(hr = 0.913, se = 0.011, p < 0.001)*. This suggests that inventors who join larger firms are more likely to stay with their new affiliation, whereas the smaller the firm, the more likely the inventor is to change organizations again, and particularly to a new patenting organization.

When split into the subsamples, 3.3% of the non-affiliated inventors will become entrepreneurs and 8.7% of those that start as garage inventors but then join an established firm are likely to spin back out again and become entrepreneurs in the sample. This could partially be seen by the *previous affiliation* variable in model 1 but is also present in the raw breakouts from the samples in Models 2 and 3.

Models 4 and 5, presented in Table 9, are designed to include proxies of personal financial resources available to the garage inventor. Model 4 includes the dummy *lawyer* indicating whether the inventor hired a lawyer to file the garage patent. This is not required for patents but could be valuable for the quality. This also demonstrates ability of the inventor to pay for a lawyer to guide them through the process and may indicate an increased preliminary motivation for a more formal business relationship later. The presence of a lawyer on a garage patent increases the likelihood of becoming an entrepreneur by 58% *(hr = 1.579, se = 0.111, p < 0.001)* while qualitatively leaving all the main effects constant.

This information is only available for patents granted after 1998 due to USPTO data availability on the measure and represents half of the initial set of garage inventors from Model 1.

Lastly, Model 5 consists of preliminary results looking at an alternative measure of resources that is not affected by the entrepreneurial intentions at the time of the first patent. Data was collected from the set of garage inventors who began their career in 2005. I was able to identify home value estimates for half of the 5,600 inventors under this condition. The estimate of the inventor's personal home, allowed to fluctuate each year based on the economic conditions in the inventor's home zip code, has some evidence for the positive relationship to transition into entrepreneurship *(hr = 1.427, se = 0.369, p = 0.100)*. Due to the extreme reduction in observations, statistical confidence intervals become quite large for nearly all the main effects, dropping below traditional statistical significance levels except for the prior connections of the patenting inventors.

Alternative Specifications

Two additional tests are completed to demonstrate the effects from Table 7. Table 10 presents the interactions included in the model. Models 2 and 3 (Table 8) split the sample but the majority of the inventors are still present in Model 2, resulting in loss of precision around estimates for those that join a firm. The full interaction model in Table 10 interacts with the main hypothesized variables with the move to an established organization and runs the full model. The interactions are included at the top for readability. All the main effects in Model 6 remain qualitatively the same, as seen in Model 2. However, the interactions highlight the organizational effects of the accumulated affiliation experience with much higher clarity and statistical confidence. One additional co-inventor on a focal patent within an existing organization now decreases the inventor's likelihood of becoming an entrepreneur by 24% *(hr = 0.761, se = 0.016, p < 0.001)*. An additional prior connection no longer helps the inventor as each additional prior connection decreases the likelihood a further 16% *(hr = 0.840, se = 0.021, p < 0.001)*. As the inventor becomes embedded in a network of co-authors and connections within an organization, he or she is less likely to spin back out. The interaction with inventor experience is negative but statistically insignificant *(hr = 0.930, se = 0.067, p = 0.312)*.

Lastly, Model 7 in Table 11 is a time-series logistic analysis on the entrepreneurial outcome by an inventor. All previous models were Cox Proportional Hazard Models that serve to include base time and inventor effects to the rate and likelihood of the entrepreneurial event. Model 7 alternatively checks this dichotomous option.

Once again, all the effects are qualitatively the same and significance levels are similar for all the main variables. The number of inventors on the patent increases the likelihood by 19% *(odds ratio = 1.193, se = 0.008, p < 0.001)*, which is right in line with Model 1. *Prior Unique Ties* increase the entrepreneurial likelihood by 14% *(or = 1.140, se = 0.010, p < 0.001)* as compared to nearly 16% originally. The inventive experience is highly significant with a 146% increased likelihood *(or = 2.457, se = 0.052, p < 0.001)*, whereas it had a hazard rate of 2.068 originally. The *previous affiliation* is also significantly present in the logistic model with a 150% increased odds (*or = 2.491, se = 0.134, p < 0.001)* as compared to the still original value of 94%.

This model does not separate out the entry and exit rates in the same manner as Model 1, demonstrating an increased likelihood of entrepreneurship as the general entrepreneurship rate increase *(or = 1.022, se = 0.007)* but also as the rate of existing firms decrease *or* $= 1.052$, *se* $= 0.010$, $p < 0.001$). The results of this test brings back the theoretical possibility that it is not simply sociological causes of entrepreneurship or even positive externalities to entrepreneurial areas and resources that promote the transition. In this case, entrepreneurs may be able to attach themselves to potential cofounders as existing companies close down and employees, existing firm resources, and knowledge are released into the environment (Carnahan, 2013; Hoetker and Agarwal, 2007).

CHAPTER 6: DISCUSSION AND CONCLUSION

Contributions

This dissertation started with the notable idea of the heroic "garage entrepreneur". The image pervades not only the entrepreneurship culture but also the broader American culture that even Cadillac has called on it and its entrepreneurs to represent their message stating "you never know what kind of greatness can come out of an American garage" (AutoMoby, 2013; Ecclestone, 2014). I use the broad construct to determine the ultimate definition of a technological entrepreneur who started through independent invention. This enables me to address entrepreneurship and technology strategy theory with clear data identification mechanisms.

This dissertation overcame some of the classic problems of entrepreneurship research (Low and MacMillan, 1988) by identifying an entrepreneurial risk-set for the level of analysis and suggesting different theoretical perspectives that affect the likelihood of becoming an entrepreneur. I started the study asking what factors are associated with the likelihood of a garage inventor becoming a garage entrepreneur, particularly proposing that the opportunity space that the inventor operates in is related to such a transition. Conditional on already having developed a garage technology in a particular technological space, the competitive conditions in that space motivate the inventor to transition to entrepreneurship. Particularly, if stronger, more concentrated firms operate in the space, the inventor is less likely to proceed to entrepreneurship. As the space increases in potential competition through other independent inventors, the garage inventor is also less likely to proceed.

Next, the geographical area contributes to the opportunity space of the potential entrepreneurs. As entrepreneurship is "in the air" as measured by the rate of any type of establishment entry in the entrepreneur's geographical area, the garage inventor is more likely to transition to entrepreneurship through a patent with a new technological entity. This likelihood is not affected by the exit rate of establishments in the inventor's area. Further, as a meaningful metric for potential technological firms, as the number of venture capital deals in the state that the inventor lives increases, the inventor is also more likely to become an entrepreneur.

The third opportunity space, social structure, is also highly important in the transition from inventor to entrepreneur. The direct and indirect inventive connections that the focal garage inventor has contributes to the positive likelihood of becoming an entrepreneur.

Lastly, increased inventive experience increases the likelihood of becoming an entrepreneur. This is significant as it shows an alternative method of learning that may be present without the organizational affiliations traditionally identified.

This effect is highlighted more prominently when separating out the inventors who stay independent up to a possible entrepreneurial event as compared to those garage inventors who patent under an existing organization prior to the end of the analysis. Joining an existing organization substitutes the need for additional direct inventive connections and dampens the importance of second-order connections' increased personal patenting experience, while possibly providing market and competitive knowledge; thus, no longer making the technological competitive landscape visible from the patent database significant.

Entrepreneurship and strategic management literature has highlighted the importance of prior organizational knowledge and connections (Agarwal et al., 2004; Agarwal and Shah, 2014; Cheyre, Klepper, and Veloso, 2015) and experience (Wadhwa et al., 2009; Wadhwa, Freeman, and Rissing, 2008). This study contributes in that line highlighting the increased entrepreneurial likelihood of inventors following organizational affiliation. I also contribute further upstream by showing earlier technical experience through patenting that demonstrates skills and interest in the direction. I show that while there is double the likelihood of entrepreneurship for these inventors, it is driven by smaller companies first and reverses key effects such as network strength. Besides patents, another modern model of the metaphorical garage is also "makerspaces" where individuals come together, have spaces and mechanical and tooling resources and encourage each other to hack new solutions to problems (Aldrich, 2014).

Limitations and Future Directions for Research

This study is not without its limitations but also not without its opportunities. First, its generalizability is limited to technological entrepreneurship of this type. Namely, for those entrepreneurs who develop an idea and patent the technology without clear organizational direction. Patenting is expensive and takes skill itself. Only certain individuals will move forward in this direction. This was a strategic choice that provides a strong data-set but it is also very limiting for those who still have a solid technological idea but do not pursue this strategy. Additionally, it is most appropriate for technologies that are well-represented in patents. Stamps.com is one case in this dataset that was only possible after the Business Method patent category was established and legalized within the United States Patent and Trademark Office classification system. Other technologies, even those with established classes, may not be well represented in this data.

The model within this dissertation treats the garage invention as if the inventor has been struck by lightning, recognizes the technology, but still does not know what to do with it as a business opportunity yet. I treat the garage invention as this exogenous event, the variation in the selection model. I use an identification strategy for invention and entrepreneurship self-contained within the USPTO database. This limits the sample of garage inventors to those who have a technology that can be patented and have the resources and initiative to do so, even when they have not created the new business yet. This is clearly undercounting the number of inventors who are developing ideas with business potential, even though those that are counted will be more likely to be stronger and highly valued (Hsu and Ziedonis, 2008, 2013) than the average venture. The identification of an entrepreneurial event also has its limitations. The assignee organization is new to the US Patent and Trademark Office but the second patent and the founding may not perfectly align. This also does not identify the garage inventors who do not file a second patent with a new technology but do indeed start a firm on the basis of the first patent, thus undercounting the rate of entrepreneurship within the sample.

While I have evidence of the clear distinction between the two events, this is not always the case. Within the random sampling of firms, 20% were founded prior to the inventor's garage patent. This presents the long-term opportunity to verify those who had pre-founded their firm and understand its effect on the empirical results. The question remains as to their motive for the first patent and the legal assignment decision that was made, particularly as they assigned a later patent to the pre-known organizational entity under their control. Future research can also continue the theoretical development to blend the invention development and entrepreneurial decision as they become more intertwined from the start and closer to the rational economic perspective of technological development and direction.

Additionally, this suggests that inventors in larger organizations with many co-inventors and connections could become embedded and are then not spinning back out as entrepreneurs, at least for those who started as garage inventors. Alternatively, this study presents the possibility to further explore the small firm effect (Elfenbein, Hamilton, and Zenger, 2010; Marx and Kacperczyk, 2015), not only as the benefits of small versus large, but identifying individuals who may be making the informed decisions to learn from one type or another, either with the goal of technical knowledge or business knowledge.

With this identification, there is clear possibility to understand the antecedents of this joining-prior-to-launching decision and exploring other aspects of the benefits of different organizational structures, whether as independent inventors or within organizations, as originally proposed by Schumpeter (1934, 1942). Lastly, this dissertation assumes through the survival analysis that entrepreneurship through starting a new business is the main desired outcome and all other results are censored observations. While starting to look at the possibility of joining an existing firm, the inventors have options to license or sell the developed technology to make profits off their labor too. These also have entrepreneurial value and may have different performance implications, whether positive or negative, endogenous to nature and quality of the technology and demand opportunities.

Implications

This study started by recalling fundamental questions in organizational and entrepreneurship research – where do new organizations come from and who is at risk of founding those organizations? By identifying a clear risk-set of potential entrepreneurs –

those inventors who independently own a patented technology – I am able to overcome the latter question to more directly answer the former. The focus of this study is the understudied area of independent inventors who have no prior organizational patenting experience, called “garage inventors” and their likelihood of becoming entrepreneurs.

I find that increased independent patenting experience and social connections can substitute for direct organizational affiliations in the likelihood of becoming an entrepreneur. Overall, the founding conditions around the technological, social, and geographical opportunity spaces are important in the transition from inventor to entrepreneur for the set of garage inventors identified in the USPTO patent database.

TABLES

Table 1: Initial Statistics from Patent Data

Description	Number	Note
Unique garage inventors in the United States	224,907	
Unique patents created by garage inventors	188,613	Some patents have multiple garage inventors
Total patent/inventor records by garage inventors over their career	406,629	On average, about 2 records per inventor
Garage inventors who become associated with *some* firm	22,988	10.2% of all garage inventors
Garage inventors who become associated with a *new* firm	11,317	49% of those who work with a firm or 6% of all garage inventors

Table 2: Descriptive Statistics

No.	Variable	Obs.	Mean	S.D.	Min	Max
(1)	Number of Inventors	311613	1.68	1.39	1	33
(2)	Claims	311532	14.12	12.39	1	683
(3)	Five-year Citations	311613	1.44	4.05	0	395
(4)	Originality	291180	0.37	0.29	0	1
(5)	Backward Citations	291180	12.43	21.29	1	1132
(6)	Other Inventor Ties	311613	0.79	1.86	0	50
(7)	Inventor Experience	311613	3.33	7.47	1	207
(8)	Male	298295	0.91	0.29	0	1
(9)	Firm Herfindahl * 10	311564	0.27	0.46	0	10
(10)	Independent Inventors in Area	311564	127.97	105.42	0	520
(11)	New Firms in Database in this year	311564	8085.34	2861.33	86	1.24E+04
(12)	Previous Affiliation	311613	0.18	0.38	0	1
(13)	Size of any Previous Affiliation	311613	522.67	3270.1	0	5.85E+04
(14)	Venture Capital Deals in State	274658	351.44	594.9	0	2948
(15)	MSA Entry Rate	278960	11.75	2.11	4.6	33.3
(16)	MSA Exit Rate	278960	10.5	1.57	4.9	28.7
(17)	Time Since Invention	311613	11.18	8.08	0	29
(18)	Lawyer	160075	0.84	0.37	0	1
(19)	Home Value Estimate	3048	541000	1,100,000	27,500	26,200,000

Table 3: Correlation Table (a)

No.	Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1)	Number of Inventors	1.000									
(2)	Claims	0.191	1.000								
(3)	Five-year Citations	-0.005	0.039	1.000							
(4)	Originality	0.124	0.133	0.023	1.000						
(5)	Backward Citations	0.170	0.167	0.006	0.196	1.000					
(6)	Other Inventor Ties	0.501	0.167	-0.043	0.098	0.093	1.000				
(7)	Inventor Experience	0.252	0.128	-0.065	0.073	0.110	0.505	1.000			
(8)	Male	-0.009	0.036	-0.007	-0.009	0.017	0.015	0.041	1.000		
(9)	Firm Herfindahl * 10	-0.031	-0.020	-0.006	-0.048	0.000	-0.018	-0.007	-0.011	1.000	
(10)	Independent Inventors in Area	-0.079	-0.029	0.042	-0.081	-0.019	-0.072	-0.066	-0.031	-0.266	1.000
(11)	New Firms in Database in this year	0.138	0.184	0.029	0.183	0.051	0.162	0.119	-0.036	-0.109	0.217
(12)	Previous Affiliation	0.509	0.218	-0.066	0.144	0.162	0.544	0.423	0.048	-0.030	-0.123
(13)	Size of any Previous Affiliation	0.239	0.060	-0.028	0.060	0.017	0.337	0.308	0.025	0.024	-0.100
(14)	Venture Capital Deals in State	0.034	0.024	0.034	0.010	0.006	0.037	0.046	-0.013	-0.001	-0.002
(15)	MSA Entry Rate	0.045	0.056	-0.083	0.006	0.023	0.100	0.101	0.042	-0.007	-0.040
(16)	MSA Exit Rate	0.000	0.024	-0.044	-0.007	0.000	0.037	0.046	0.017	-0.003	-0.004
(17)	Time Since Invention	-0.085	-0.138	0.144	-0.132	-0.063	-0.104	-0.012	0.000	0.038	-0.044
(18)	Lawyer	0.050	0.090	-0.008	0.035	0.036	0.036	0.036	0.038	-0.011	-0.005
(19)	Home Value Estimate	-0.006	0.033	0.022	0.034	-0.008	0.034	0.026	-0.032	0.009	-0.016

Table 4: Correlation Table (b)

No.	Variable	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
(11)	New Firms in Database in this year	1.000								
(12)	Previous Affiliation	0.196	1.000							
(13)	Size of any Previous Affiliation	0.074	0.340	1.000						
(14)	Venture Capital Deals in State	0.084	0.038	0.005	1.000					
(15)	MSA Entry Rate	-0.037	0.108	0.032	0.091	1.000				
(16)	MSA Exit Rate	0.002	0.032	-0.007	0.162	0.678	1.000			
(17)	Time Since Invention	-0.324	-0.084	-0.020	0.044	-0.354	-0.212	1.000		
(18)	Lawyer	-0.008	0.100	0.023	-0.023	0.023	-0.001	0.018	1.000	
(19)	Home Value Estimate	-0.056	0.009	-0.006	0.223	0.100	0.088	-0.048	0.042	1.000

Table 5: Descriptive Statistics by Entrepreneurship Condition

		Garage Entrepreneur = 1				Garage Entrepreneur = 0			
No.	Variable	Mean	Std. Dev	Min	Max	Mean	Std. Dev.	Min	Max
(1)	Number of Inventors	1.99	1.4	1	27	1.67	1.39	1	33
(2)	Claims	16.44	13.53	1	195	14.06	12.36	1	683
(3)	Five-year Citations	1.51	3.9	0	82	1.44	4.06	0	395
(4)	Originality	0.38	0.29	0	0.9363	0.37	0.29	0	1
(5)	Backward Citations	13.04	17.18	1	672	12.41	21.39	1	1132
(6)	Other Inventor Ties	0.96	1.24	0	21	0.79	1.87	0	50
(7)	Inventor Experience	2.76	4.6	1	207	3.34	7.53	1	207
(8)	Male	0.95	0.22	0	1	0.91	0.29	0	1
(9)	Firm Herfindahl	0.24	0.42	0	10	0.27	0.46	0	10
(10)	Independent Inventors in Tech Area	127.36	106.48	0	520	127.98	105.41	0	520
(11)	New Firms in Database in this Year	8069.99	2745	822	1.24E+04	8085.06	2864	86	1.24E+04
(12)	Previous Affiliation	0.18	0.39	0	1	0.18	0.38	0	1
(13)	Size of any Previous Affiliation	130.84	1292	0	4.85E+04	533.64	3308	0	5.85E+04
(14)	Venture Capital Deals in State	302.89	539	0	2948	352.84	596	0	2948
(15)	MSA Entry Rate	12.95	2.13	7.6	33.3	11.72	2.1	4.6	33.3
(16)	MSA Exit Rate	10.91	1.54	5.7	25.3	10.48	1.57	4.9	28.7
(17)	Time Since Invention	5.95	4.99	0	28	11.33	8.1	0	29
(18)	Lawyer	0.88	0.32	0	1	0.84	0.37	0	1
(19)	Home Value Estimate	647,000	482,000	112,000	2,300,000	540,000	1,100,000	27,500	26,200,000

Table 6: Garage Invention and Entrepreneurship Statistics by State

State	Garage Inventors	Garage Inventors per Million Residents	Garage Entrepreneurs	Garage Entrepreneurs per Million Residents
Alabama	1,629	2,779.47	40	68.25
Alaska	473	110.82	3	0.70
Arizona	4,422	1,744.36	149	58.77
Arkansas	907	205.32	24	5.43
California	33,651	1,079.07	1,409	45.18
Colorado	3,863	1,003.78	189	49.11
Connecticut	3,115	932.96	127	38.04
Delaware	416	572.13	9	12.38
Florida	13,072	909.44	376	26.16
Georgia	3,753	509.94	143	19.43
Hawaii	718	616.89	12	10.31
Idaho	1,147	95.71	33	2.75
Illinois	8,162	1,394.77	281	48.02
Indiana	2,991	1,036.21	112	38.80
Iowa	1,569	1,325.23	47	39.70
Kansas	1,615	624.66	60	23.21
Kentucky	1,335	341.83	45	11.52
Louisiana	2,873	655.09	90	20.52
Maine	706	114.97	25	4.07
Maryland	3,761	751.61	128	25.58
Massachusetts	5,276	4,253.92	237	191.09
Michigan	7,737	806.37	278	28.97
Minnesota	4,233	911.80	204	43.94
Mississippi	7,737	1,439.75	278	51.73
Missouri	3,097	1,137.59	112	41.14

Table 6 (continued)

Montana	800	921.85	29	33.42
Nebraska	1,080	940.59	29	25.26
Nevada	1,541	208.22	53	7.16
New Hampshire	1,077	133.43	47	5.82
New Jersey	6,662	3,977.78	262	156.43
New Mexico	1,088	58.95	44	2.39
New York	13,427	20,594.70	473	725.50
North Carolina	3,850	2,318.31	150	90.33
North Dakota	524	321.72	14	8.60
Ohio	6,194	556.91	239	21.49
Oklahoma	2,241	668.97	65	19.40
Oregon	2,994	951.26	132	41.94
Pennsylvania	7,354	605.81	216	17.80
Rhode Island	635	624.28	17	16.71
South Carolina	1,820	483.16	65	17.26
South Dakota	451	615.08	16	21.82
Tennessee	2,506	470.87	73	13.72
Texas	11,419	596.75	412	21.53
Utah	2,156	1,069.44	118	58.53
Vermont	482	72.86	23	3.47
Virginia	3,903	6,748.09	151	261.07
Washington	4,599	858.70	174	32.49
West Virginia	607	118.05	15	2.92
Wisconsin	3,494	1,893.67	148	80.21
Wyoming	417	843.26	9	18.20

Table 7: Results (a) – Cox Proportional Hazard Models

Description	Model 1 Full Model
Main Independent Variables	
Number of Inventors	1.194*** (0.008)
Prior Unique Ties of Inventors	1.157*** (0.009)
Firm Herfindahl (0-10)	0.692*** (0.038)
Total Independent in Tech Area (log)	0.890*** (0.014)
Venture Capital Deals in State (log)	1.035*** (0.009)
MSA Entry Rate	1.024** (0.008)
MSA Exit Rate	0.987 (0.012)
Inventor Experience (log)	2.068*** (0.056)
Previous Affiliation	1.936*** (0.112)
Size of Previous Affiliation (log)	0.763*** (0.010)
Time Since (years)	0.935*** (0.004)
Control Variables	
Claims (log)	1.367*** (0.023)
Five-year Citations	0.999 (0.003)
Originality	1.270*** (0.063)
Backward Citations	1.003*** (0.001)
Male (=1)	2.185*** (0.137)
New Firms in Database (log)	2.975*** (0.266)
Observations	1,975,063
Number of Subjects	152,092
Number of Events	5,684
Log-likelihood	-61,077.53

+ $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Standard errors in parentheses; Hazard Ratio presented
Cox Proportional Hazard Model regression with hazard rates presented. Outcome is the incident of generating a patent with a new technological firm in the year following the independent variables.
All other outcomes are considered censored in the model. To calculate coefficients, calculate ln(hazard rate). For example, the inventor experience variable coefficient in Model 1 would be ln(2.156) = 0.768.

Table 8: Results (b) – Cox Proportional Hazard Models

Description	Model 2 Non-affiliated inventors	Model 3 Inventors who become affiliated
Main Independent Variables		
Number of Inventors	1.265***	0.952*
	(0.006)	(0.021)
Prior Unique Ties of Inventors	1.202***	1.042*
	(0.009)	(0.020)
Firm Herfindahl (0-10)	0.589***	0.835
	(0.039)	(0.117)
Total Independent in Tech Area (log)	0.856***	1.025
	(0.015)	(0.035)
Venture Capital Deals in State (log)	1.039***	1.069**
	(0.010)	(0.023)
MSA Entry Rate	1.019*	1.030
	(0.009)	(0.022)
MSA Exit Rate	0.978	0.983
	(0.013)	(0.033)
Inventor Experience (log)	2.196***	1.907***
	(0.070)	(0.100)
Previous Affiliation		
Size of Previous Affiliation (log)		0.913***
		(0.011)
Time Since (years)	0.924***	0.982*
	(0.006)	(0.007)
Control Variables		
Claims (log)	1.427***	1.246***
	(0.027)	(0.053)
Five-year Citations	0.999	0.986+
	(0.003)	(0.008)
Originality	1.218***	1.375**
	(0.066)	(0.168)
Backward Citations	1.006***	1.003**
	(0.001)	(0.001)
Male (=1)	2.451***	1.332+
	(0.172)	(0.198)
New Firms in Database (log)	3.086***	1.910***
	(0.348)	(0.317)
	1,838,365	136,698

Observations		
Number of Subjects	140,913	11,179
Number of Events	4,717	967
Log-likelihood	-50,044.72	-8,245.02

+ $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Standard errors in parentheses; Hazard Ratio presented
Cox Proportional Hazard Model regression with hazard rates presented. Outcome is the incident of generating a patent with a new technological firm in the year following the independent variables.
All other outcomes are considered censored in the model.

Table 9: Results (c) – Cox Proportional Hazard Models

Description	Model 4 1998 onward	Model 5 2005 Model with Home Value
Main Independent Variables		
Number of Inventors	1.145***	1.154
	(0.012)	(0.342)
Prior Unique Ties of Inventors	1.103***	5.406*
	(0.014)	(4.026)
Firm Herfindahl (0-10)	0.795**	1.486
	(0.066)	(0.986)
Total Independent in Tech Area (log)	0.896***	1.982+
	(0.020)	(0.773)
Venture Capital Deals in State (log)	1.042**	1.087
	(0.013)	(0.226)
MSA Entry Rate	1.031*	0.998
	(0.015)	(0.194)
MSA Exit Rate	1.012	1.021
	(0.026)	(0.359)
Inventor Experience (log)	1.876***	0.000
	(0.068)	(0.000)
Previous Affiliation	1.972***	0.000
	(0.154)	(0.000)
Size of Previous Affiliation (log)	0.783***	54.736
	(0.013)	(2.87e10)
Time Since (years)	0.958***	0.000
	(0.006)	(0.000)
Control Variables		
Claims (log)	1.270***	0.655
	(0.033)	(0.206)
Five-year Citations	0.993	1.304
	(0.005)	(0.233)
Originality	1.366***	8.618+
	(0.105)	(10.979)
Backward Citations	1.003***	0.986
	(0.001)	(0.024)
Male (=1)	1.811***	2.235
	(0.149)	(2.354)
New Firms in Database (log)	0.985	0.623
	(0.131)	(0.000)
Lawyer	1.579***	2.4e16
	(0.111)	(0.000)

Zillow Estimate of Home Value		1.427+
		(0.369)
Observations	658,241	9,246
Number of Subjects	79,061	2,328
Number of Events	2,485	18
Log-likelihood	-25,630.14	-78.80

+ $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Standard errors in parentheses; Hazard Ratio presented
Cox Proportional Hazard Model regression with hazard rates presented. Outcome is the incident of generating a patent with a new technological firm in the year following the independent variables.
All other outcomes are considered censored in the model.

Table 10: Interaction Model with Post-Firm Affiliation (Cox Model)

Description	Model 6 Full Interaction Model
Interacted Variables with Post-Firm Affiliation	
x.Number of Inventors	0.761*** (0.016)
x.Prior Unique Ties of Inventors	0.840*** (0.021)
x.Inventor Experience (log)	0.930 (0.067)
x.Firm Herfindahl (0-10)	1.505** (0.224)
x.Total Independent in Tech Area (log)	1.234*** (0.042)
x.Venture Capital Deals in State (log)	1.067** (0.025)
x.MSA Entry Rate	1.040+ (0.022)
x.MSA Exit Rate	0.979 (0.028)
Main Independent Variables	
Number of Inventors	1.257*** (0.007)
Prior Unique Ties of Inventors	1.191*** (0.009)
Firm Herfindahl (0-10)	0.622*** (0.039)
Total Independent in Tech Area (log)	0.861*** (0.014)
Venture Capital Deals in State (log)	1.028** (0.010)
MSA Entry Rate	1.018* (0.009)
MSA Exit Rate	0.987 (0.013)
Inventor Experience (log)	2.078*** (0.060)
Previous Affiliation	1.259** (0.110)
Size of Previous Affiliation (log)	0.808*** (0.013)
Time Since (years)	0.935*** (0.004)

Control Variables	
Claims (log)	1.371***
	(0.024)
Five-year Citations	0.998
	(0.003)
Originality	1.242***
	(0.062)
Backward Citations	1.004***
	(0.001)
Male (=1)	2.235***
	(0.142)
New Firms in Database (log)	2.982***
	(0.267)
Observations	1,975,063
Number of Subjects	152,092
Number of Events	5,684
Log-likelihood	-60,825.01

+ $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Standard errors in parentheses; Hazard Ratio presented
Cox Proportional Hazard Model regression with hazard rates presented. Outcome is the incident of generating a patent with a new technological firm in the year following the independent variables.
All other outcomes are considered as censored in the model. All subjects started as garage inventors but the *x*. variables refer to the interaction after some become affiliated to a non-entrepreneurial company.

Table 11: Robustness Test – Logit Model

Description	Model 7 Logit Model
Number of Inventors	1.193*** (0.008)
Prior Unique Ties of Inventors	1.140*** (0.010)
Firm Herfindahl (0-10)	0.730*** (0.037)
Total Independent in Tech Area (log)	0.920*** (0.013)
Venture Capital Deals in State (log)	0.993 (0.008)
MSA Entry Rate	1.022** (0.007)
MSA Exit Rate	1.052*** (0.010)
Inventor Experience (log)	2.457*** (0.052)
Previous Affiliation	2.491*** (0.134)
Size of Previous Affiliation (log)	0.735*** (0.009)
Time Since (years)	0.890*** (0.003)
Claims (log)	1.340*** (0.022)
Five-year Citations	0.998 (0.003)
Originality	1.169*** (0.055)
Backward Citations	1.000 (0.001)
Male (=1)	2.271*** (0.134)
New Firms in Database (log)	1.013 (0.039)
Observations	2,209,321
Number of Groups	153,184
Wald χ^2	9,058.89
Prob > χ^2	0.00

* $p<0.05$; ** $p<0.01$; *** $p<0.001$

xtgee command in stata based on a time-series logistic analysis. Standard errors in parentheses; odds ratio presented; Event is a further patent with a garage entrepreneurial firm.

FIGURES

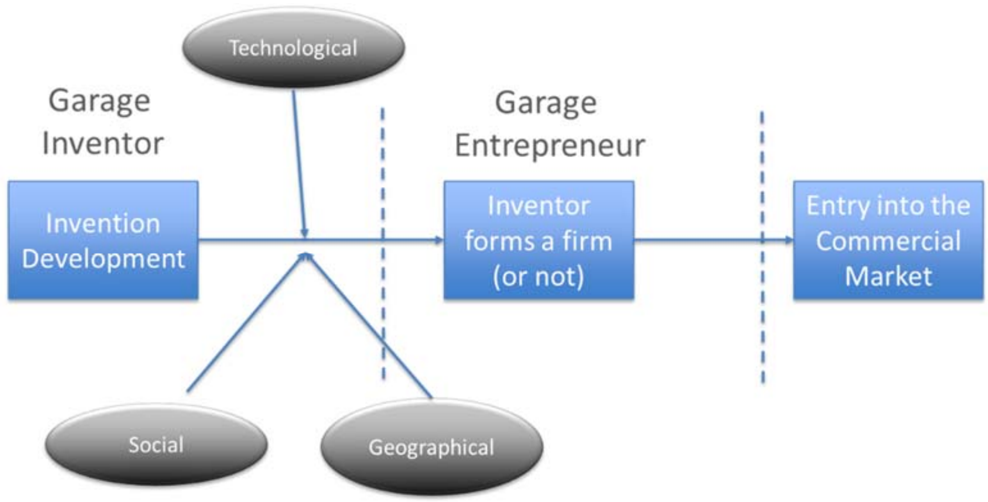


Figure 1: Basic Model of Garage Entrepreneurship[1]

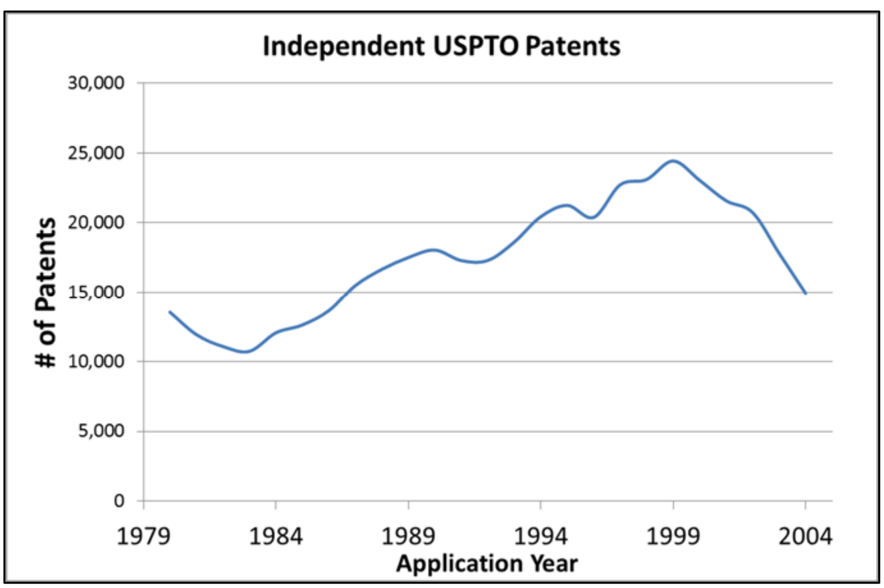


Figure 2: USPTO Patents by Independent Inventors: 1980 – 2004

[1] Adapted from the model with *prior knowledge* from Shane (2000) as well as the "User Entrepreneurship Model" in Shah and Tripsas (2007: 129) as compared to the "Classic Entrepreneurship Model" starting with Opportunity Identification, firm formation, and development of solution.

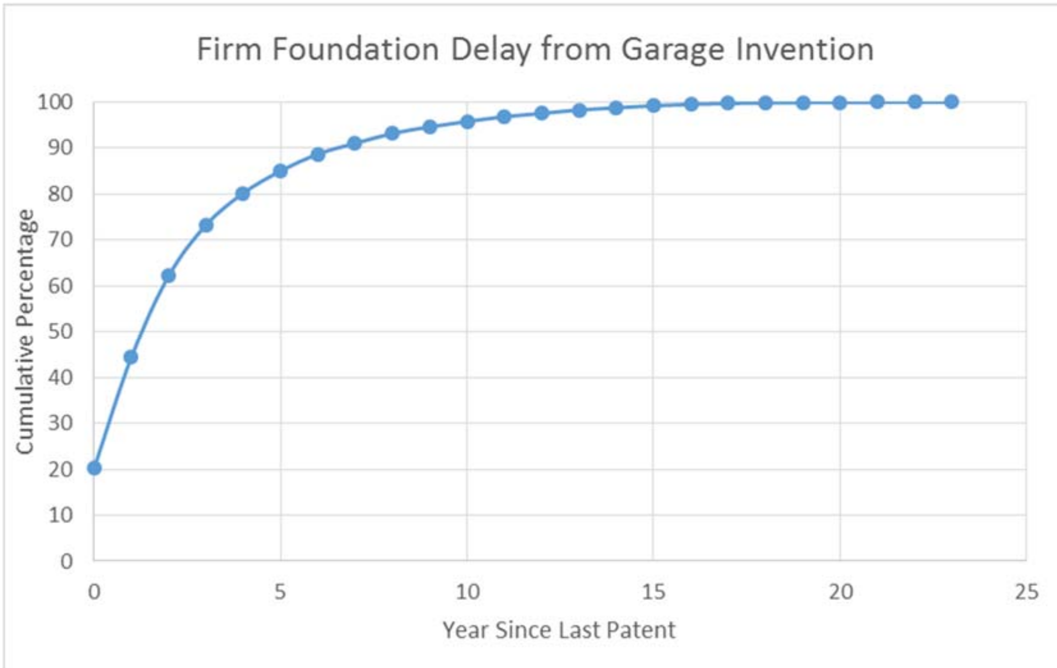


Figure 3: Firm Foundation Delay from Last Patent for Garage Inventors

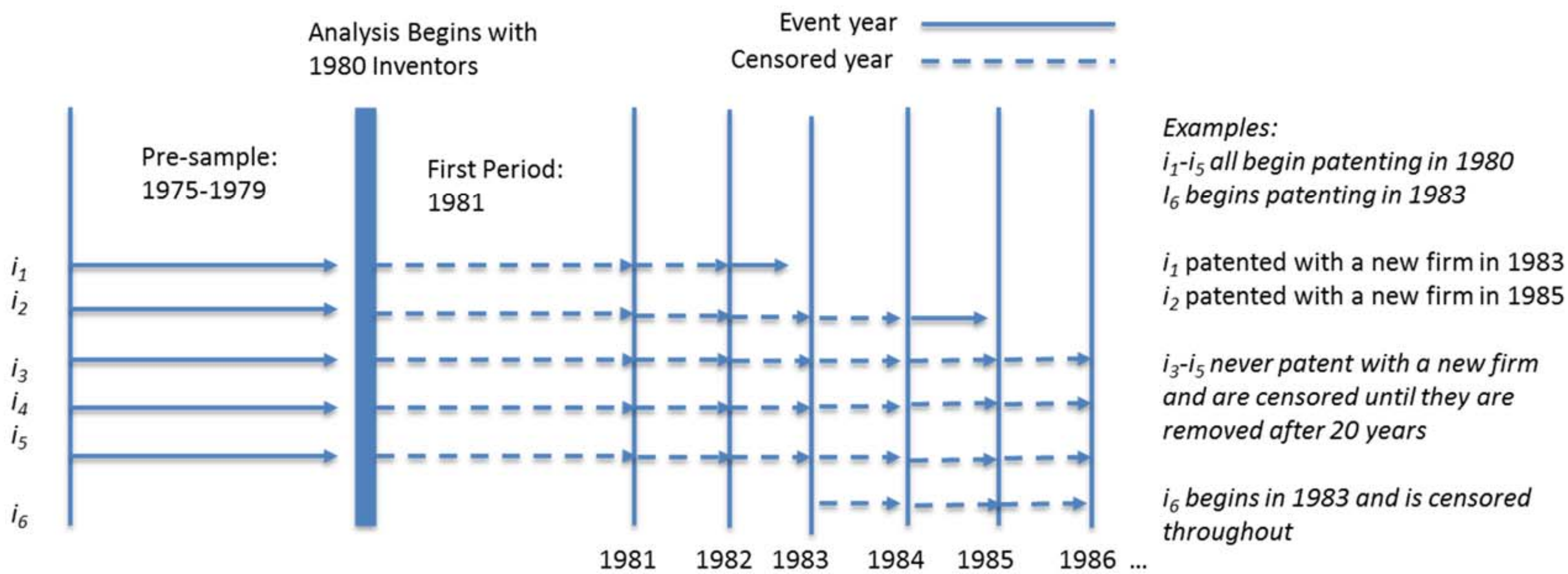


Figure 4: Example of Survival Analysis Data Structure

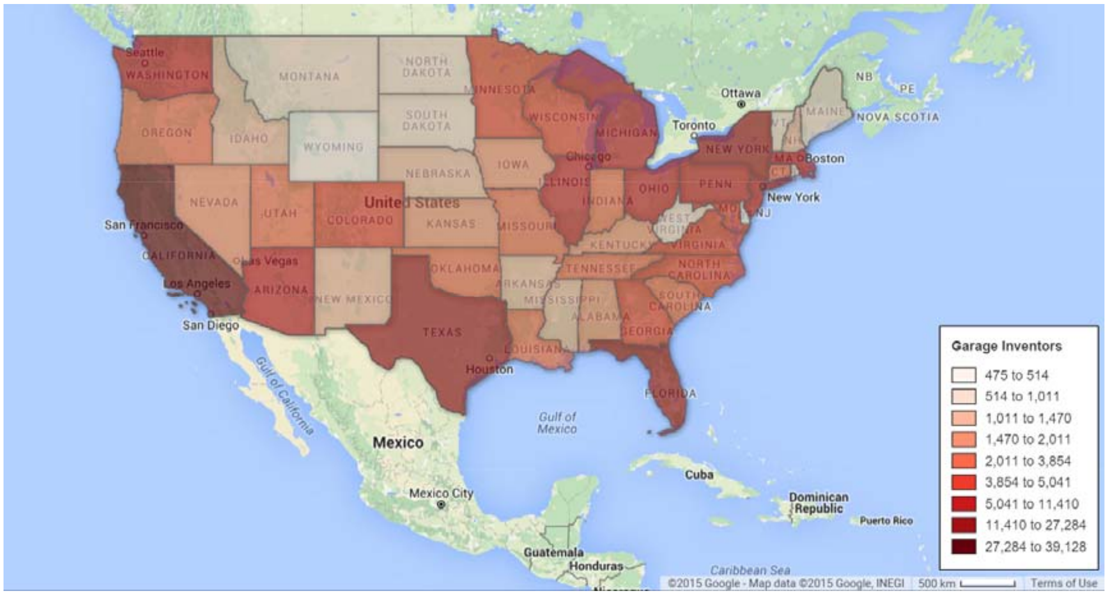


Figure 5: Garage Inventors by State

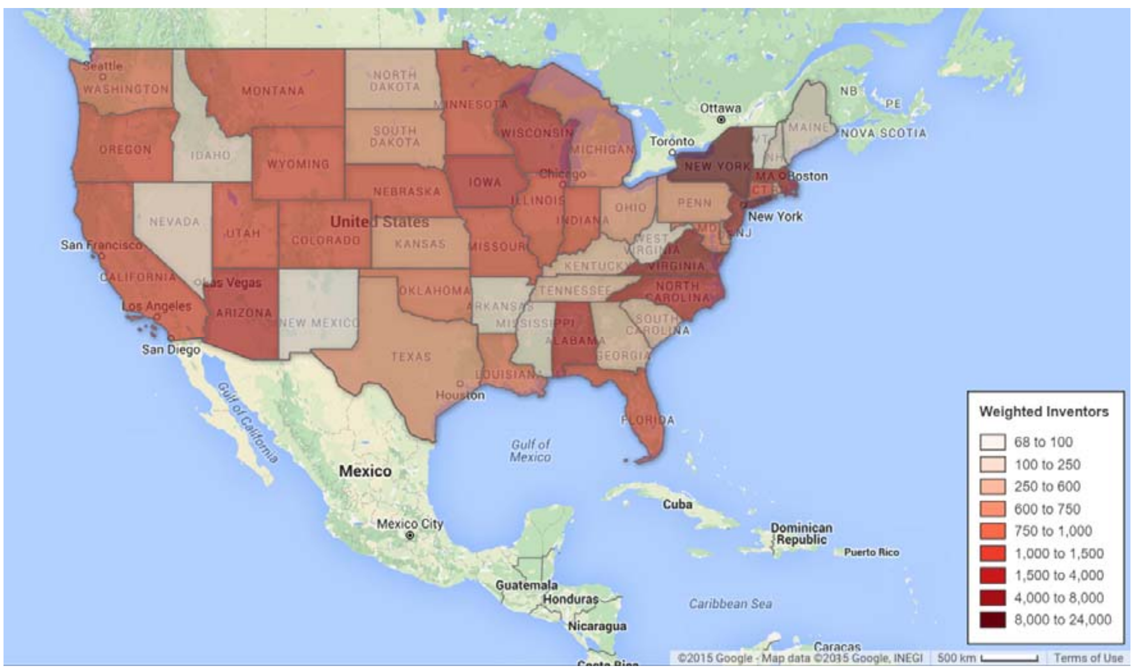


Figure 6: Garage Inventors Weighted by State Population (per million)

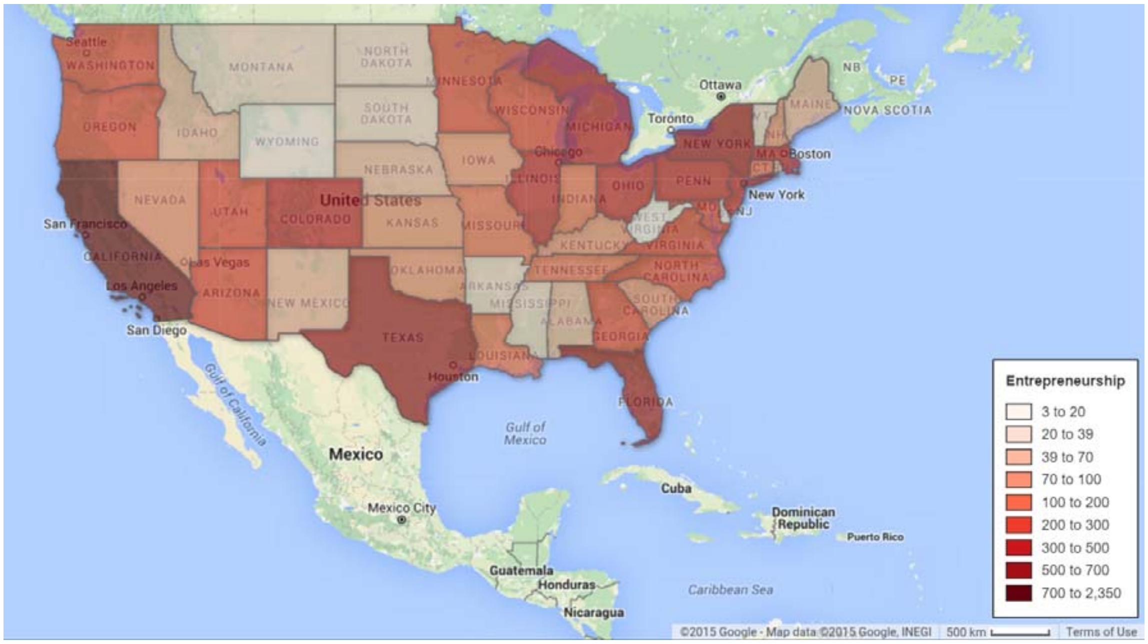


Figure 7: Garage Entrepreneurs by State

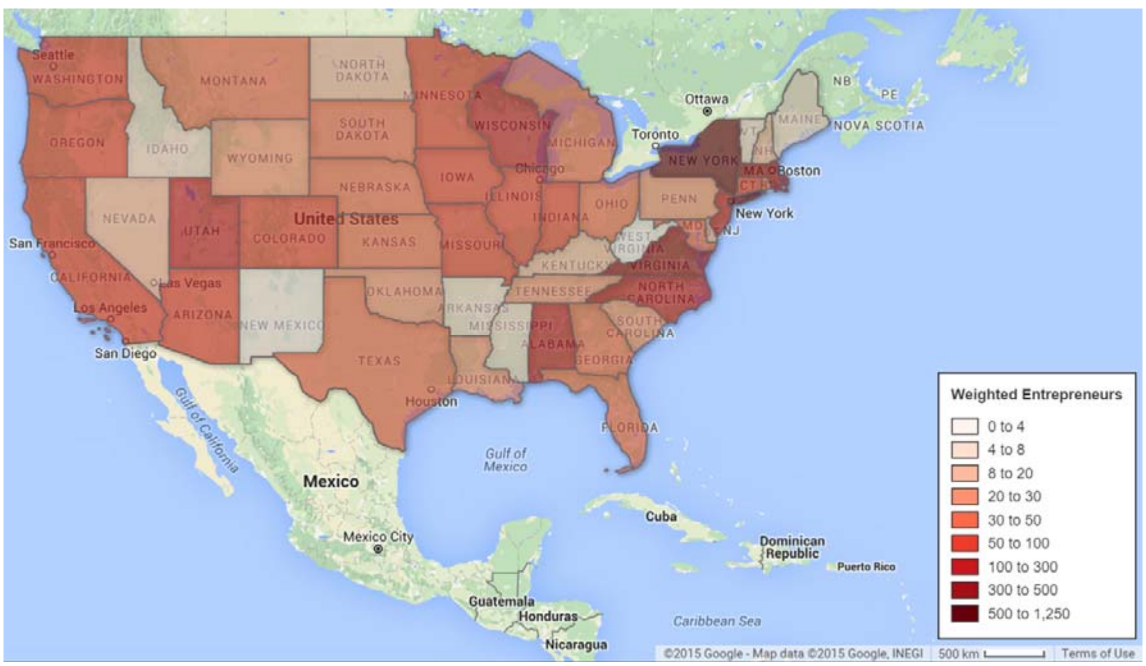


Figure 8: Garage Entrepreneurs Weighted by State Population (per million)

APPENDIX: COMPANY VERIFICATION

Identification

This section details a process verification of the new firms identified within the patent database. The data identification for this study relies on two definitions:

1) Initial patenting career of an inventor as an independent inventor without prior organizational affiliation.
2) Starting of a new company identified as a new patenting organization within the USPTO database.

The theoretical model for this dissertation does not necessarily hinge on absolutely no prior organizational experience but does want to disconnect the knowledge creation, or the "aha moment," for the first invention from a model of clear knowledge spillover from previous technical positions. The empirical definition was chosen to limit that link to prior jobs that may have provided more direct inspiration than my model allows. Additionally, if the inventor has a direct employment contract, the garage technology should be assigned to the established organization. This could be more disconnected if the inventor already is an entrepreneur with a company and sees no difference between assigning the garage patent to himself/herself or his/her organization, creating an identification error for my analysis. This also has a positive effect for future related study in this area by selecting those individuals who are actually entrepreneurs and owners rather than employees of other organizations.

This possible identification error is then related to the identification of number 2 also. The firm is indeed a new entity within the patenting data but the question is when did the company actually get founded? This can affect the time series analysis as to when to apply environmental conditions to the decision to become an entrepreneur. This also affects the theoretical model separating the invention decision from the entrepreneurship decision. I performed a manual search process in order to validate the firm identification. I randomized the list of new firms from the data but manually searched for information about them with a goal of 2–3 per year from the sample. This resulted in searching for 72 firms that I had identified as new patenting organizations during 1980 – 2009. The summary by year is presented in Table 12.

Table 12: Firm Founding Verification Table by Year

Year	No. Checked	Newly Founded	Pre-Founded	No Info
1980	2	1	1	0
1981	1	0	1	0
1982	2	1	0	1
1983	2	2	0	0
1984	2	2	0	0
1985	2	1	0	1
1986	2	1	0	1
1987	3	1	1	1
1988	2	1	1	0
1989	2	1	1	0
1990	2	2	0	0
1991	3	1	1	1
1992	2	2	0	0
1993	3	1	1	1
1994	2	1	1	0
1995	3	1	0	2
1996	3	2	0	1
1997	3	1	1	1
1998	2	2	0	0
1999	2	1	0	1
2000	3	2	0	1
2001	2	2	0	0
2002	3	2	0	1
2003	2	2	0	0
2004	4	2	1	1
2005	4	2	1	1
2006	2	2	0	0
2007	2	2	0	0
2008	3	2	0	1
2009	2	2	0	0

**The early years (1980-1982) represent all the "new firms" in the USPTO database given the garage inventor to garage entrepreneur definition.*

The full summary of the validation is presented in Table 13. I searched for 72 firms and was able to verify information for 56 of them, or about 78%. Of the 56 that I could verify, 80%

of them were founded after the date of the inventor's garage invention. I found that the other 20% of the firms were incorporated prior to the garage invention.

Table 13: Summary of Firm Founding Verification

Status	Count of Firms	% of Known	% of All Searched
Total Checked	72		
Total Found	56		
Total Newly Founded	45	80%	63%
Total Pre-Founded	11	20%	15%
Total No Info	16		22%

I now detail examples of the verification process.

Example Search Process and Vignettes

To verify the information on firm foundings, I researched each firm and the known inventor through Google to collect information. This started with a survival and success bias for the firms that still had websites or had founder stories available. The next few firms all represent different categories of garage inventors and entrepreneurs that were originally in the data and information could be found.

Paice, LLC

Alex Severinsky founded Paice, LLC to commercialize patents he developed concerning hybrid vehicle technology. Severinsky held a PhD in Electrical Engineering and was working as an instructor at the University of Maryland's engineering school. He developed patent 5,343,970 for a "Hybrid electric vehicle" and filed for a patent on September 21, 1992, which was granted on September 6, 1994 (Severinsky, 1994). This patent was assigned to him alone. Recognizing the potential value, he applied for and was admitted into the University of Maryland's business incubator program. According to the Paice website history, Dr. Severinsky's interest in finding a solution to car efficiency problems was aroused while waiting in line for gas in the late 1970's (Alex Severinsky | Hybrid Technologist | Paice Hybrid LLC, 2013). Following this, he founded Paice, LLC and subsequently developed more patents related to hybrid vehicles including:

- Patent 6,209,672 refining the "hybrid vehicle" design on September 9, 1999 and is assigned to Paice. (Severinsky, 2001)
- Patent for "Engine start and shutdown control in hybrid vehicles" on September 10, 1999 that is co-invented and assigned to Paice (Severinsky and Louckes, 2011).

These patents are significant in defining the functional operating range for hybrid vehicle connections. The American Society of Mechanical Engineers has recognized Dr. Severinsky's technical accomplishments as significant by awarding him the Thomas A. Edison Patent Award for technologies of importance for breakthroughs or that lead to valuable companies.

A patent attorney firm performed an analysis of the hybrid industry and concluded that Paice held four of the top nine most dominant patents by citations (Lloyd and Blows, 2009). Paice has won lawsuits for patent infringement against Ford and Toyota resulting in a forced licensing fee for their hybrid car sales. Paice has open lawsuits against Kia and Hyundai. (Paice, LLC, 2010).

However, this was not his first venture. Dr. Severinsky had previously founded Viteq which developed uninterrupted power supplies for computers. He developed 14 patents between 1987 (Severinsky, 1989) and 1991 (Severinsky, 1989) for Viteq before he sold the business. While this company fits the pattern of independent invention turned new firm, due to his prior patenting relationship, Dr. Severinsky and Paice is removed from the strict identification analysis for this study but offers more opportunity for future study.

Lastly, Dr. Severinsky stepped down as the CEO of Paice in 2006 and founded a new company, Fuelcor.

Denecke, Inc.

Denecke, Inc. makes electronic time code slates for the movie and entertainment businesses. A time code slate is the "clapper" used by directors at the beginning of shots. The founder, Mike Denecke, was working on film sets at the time as a sound and electronic designer. The owner of another firm, Ivan Kruglak from Coherent Communications, introduced Mike to one of the first electronic time slates in 1985. Mike recognized the value of syncing multiple shots electronically but the product was not taking off (Denecke, 1997b). Under his legal name, Henry M. Denecke applied for a patent for a "Time Code Decoder" on May 24, 1985, which would result in patent 4,646,167 granted on February 24, 1987 (Denecke, 1987). Mike Denecke is the owner of this patent. Before this, Mike Denecke was also the inventor of two patents:

- Patent 4,227,126 applied for on February 21, 1978 for a "Shaft rotation interlock system for film editing tables and the like" (Denecke, 1980).
- Patent 4,328,484 applied for on September 2, 1980 for a "Method and apparatus for numerically converting a parallel binary coded number from a first unit system to a second unit system (Denecke, 1982).

Following these non-assigned patents, Mike filed for a patent for a "Battery Holder", numbered 5,601,940 on May 11, 1995 under the company name "Denecke, Inc." (Denecke, 1997a). The Denecke time code slates are the "industry standard" according to their website (Denecke, 1997b).

Denecke, Inc. was actually founded in 1975 by Mike Denecke as a personal venture. He diversified into the technology market as he saw a demand and could develop the product (Denecke, 1997b). Due to this reason, he qualifies under the initial patent-level identification strategy but would be removed upon full company verification.

Braintexter Inc.

Founded by Riccardo and Flavio Vieri, Braintexter Inc. holds patents regarding short message service (SMS) texting. Specifically, they independently developed a patent to convert SMS text to speech (Vieri, Tomasso, and Vieri, 2007) in 2003. Subsequently, they developed a method for applying contextual advertising based on the sender, receiver, and content of text messages in 2009 (Vieri, 2009) and 2013 (Vieri, 2013). The text-to-speech patent was independently owned but the advertising patents were subsequently assigned to their new firm, Braintexter Inc (Braintexter Inc: About Us, 2010). In 2008, Braintexter, Inc., was incorporated in Delaware (Bizapedia, 2014) and Riccardo and Flavio Vieri reassigned their older patents to the firm. In 2011, Braintexter's patents were sold and reassigned to Apple (Vieri et al., 2007).

Dietrick Sports Products

Donald E. Cech developed patent 5,630,652 for a "releasable axle assembly for skate wheels" (Cech, 1997) in 1995 and created the company Dietrick Sports Products, Inc. Prior to this, Donald Cech has developed two previous patents related to skating – Patent 5,226,673 for a "Braking Assembly and Method" in 1991 (Cech, 1993) and Patent 5,351,974 for "In-line skate braking assembly and method" in 1992 (Cech, 1994).

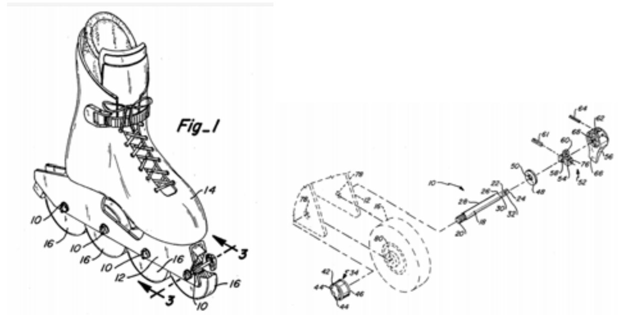
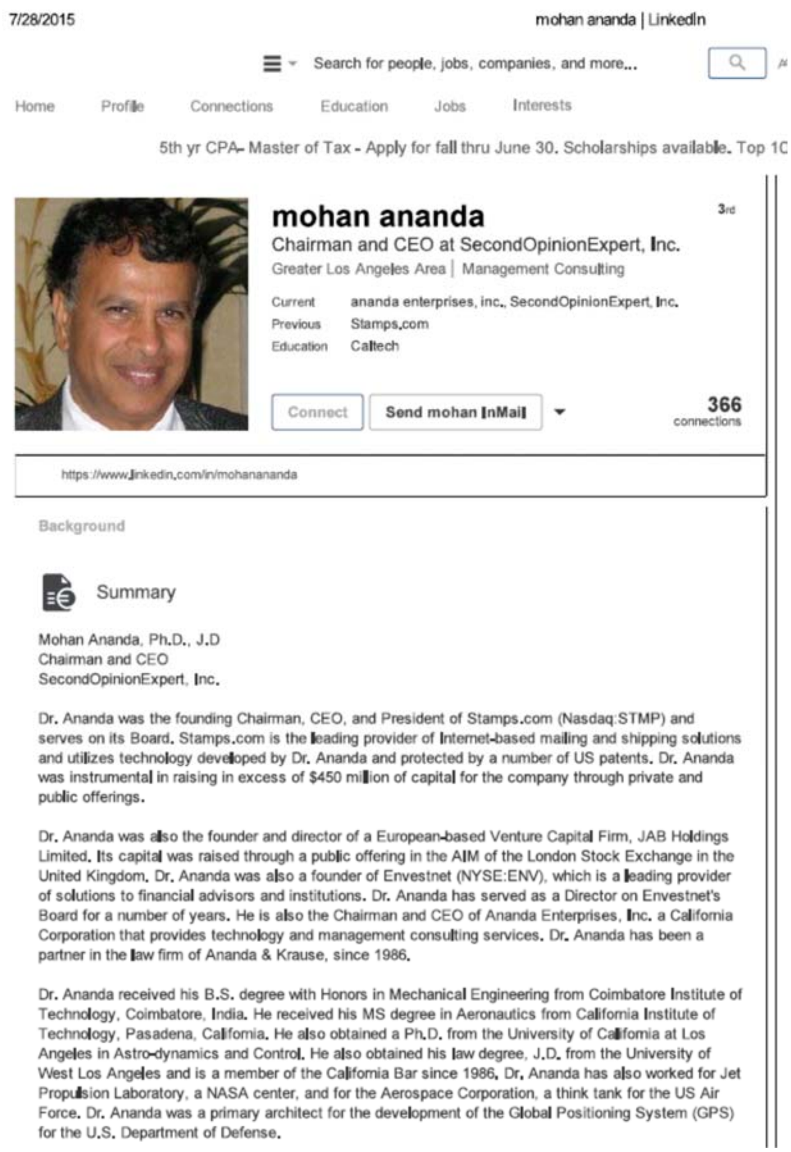


Figure 9: Donald Cech's Invention of "Releasable Axle Assembly for Skate Wheels"

Living in Colorado, he assigned this patent to a new firm, Dietrick Sports Products, Inc. in Steamboat Springs, Colorado (Cech, 1997).

Stamps.com, Inc.

Mohan Ananda is the founding CEO of Stamps.com, which is highlighted by his public LinkedIn profile in Figure 10. He has three independent patents and starts his patenting career as a garage inventor within the newly developed "Business Method Patents" class 705 in the USPTO classification system. All of his original three patents start with the title "Secure software rental system using… (Ananda, 1996a, 1996b, 1997)." His fourth patent, 6,671,813 (Ananda, 2003), is filed under Stamps.com, which does cite one of his earlier patents. It is the first patent by that organization. This patent is for "Secure on-line PC postage metering system." He then has four more patents under the organization Stamps.com. By the time he has his fifth organizational patent, it is actually the 27th patent for Stamps.com overall. He ends with two more independent patents to end his patenting career within this data, for a total of 10 patents.



7/28/2015 mohan ananda | LinkedIn

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5th yr CPA- Master of Tax - Apply for fall thru June 30. Scholarships available. Top 1C

mohan ananda

3rd

Chairman and CEO at SecondOpinionExpert, Inc.

Greater Los Angeles Area | Management Consulting

Current ananda enterprises, inc., SecondOpinionExpert, Inc.

Previous Stamps.com

Education Caltech

Connect | Send mohan InMail

366 connections

https://www.linkedin.com/in/mohanananda

Background

Summary

Mohan Ananda, Ph.D., J.D
Chairman and CEO
SecondOpinionExpert, Inc.

Dr. Ananda was the founding Chairman, CEO, and President of Stamps.com (Nasdaq:STMP) and serves on its Board. Stamps.com is the leading provider of Internet-based mailing and shipping solutions and utilizes technology developed by Dr. Ananda and protected by a number of US patents. Dr. Ananda was instrumental in raising in excess of $450 million of capital for the company through private and public offerings.

Dr. Ananda was also the founder and director of a European-based Venture Capital Firm, JAB Holdings Limited. Its capital was raised through a public offering in the AIM of the London Stock Exchange in the United Kingdom. Dr. Ananda was also a founder of Envestnet (NYSE:ENV), which is a leading provider of solutions to financial advisors and institutions. Dr. Ananda has served as a Director on Envestnet's Board for a number of years. He is also the Chairman and CEO of Ananda Enterprises, Inc. a California Corporation that provides technology and management consulting services. Dr. Ananda has been a partner in the law firm of Ananda & Krause, since 1986.

Dr. Ananda received his B.S. degree with Honors in Mechanical Engineering from Coimbatore Institute of Technology, Coimbatore, India. He received his MS degree in Aeronautics from California Institute of Technology, Pasadena, California. He also obtained a Ph.D. from the University of California at Los Angeles in Astro-dynamics and Control. He also obtained his law degree, J.D. from the University of West Los Angeles and is a member of the California Bar since 1986. Dr. Ananda has also worked for Jet Propulsion Laboratory, a NASA center, and for the Aerospace Corporation, a think tank for the US Air Force. Dr. Ananda was a primary architect for the development of the Global Positioning System (GPS) for the U.S. Department of Defense.

Figure 10: Mohan Ananda LinkedIn Profile - Stamps.com

Metcast Associates

The next series of organizations have better founding information. Figure 11 is a cut-out of the patent page for Daniel Groteke's first patent. Mr. Groteke lives on 1228 Ridge Cliff Rd., Cincinnati, Ohio and files for what will become patent 4,394,271 on April 23, 1981 for an "Apparatus and Method for Filtration of Molten Metal" (Groteke, 1983).

United States Patent [19] — Groteke

[11] **4,394,271**

[45] **Jul. 19, 1983**

[54] **APPARATUS AND METHOD FOR FILTRATION OF MOLTEN METAL**

[76] Inventor: **Daniel E. Groteke**, 1228 Ridge Cliff Rd., Cincinnati, Ohio 45215

[21] Appl. No.: **256,829**

[22] Filed: **Apr. 23, 1981**

[51] **Int. Cl.**³ **C22B 9/02**

[52] **U.S. Cl.** .... **210/773**; 210/471; 210/510; 75/68 R; 266/227; 266/238

[58] **Field of Search** .... 210/773, 470, 471, 510, 210/767, 774; 75/93 E, 68 R; 266/227, 238, 242

[56] **References Cited**

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3,149,960	9/1964	Robinson	75/68
3,537,987	11/1970	Copeland	210/20
3,654,150	4/1972	Eccles	210/69
3,729,097	4/1973	Collins et al.	210/69
3,737,304	6/1973	Blaydon et al.	75/68 R
3,962,081	6/1976	Yarwood	210/69
4,007,923	2/1977	Chia	266/217
4,024,056	5/1977	Yarwood et al.	210/69
4,081,371	3/1978	Yarwood et al.	210/69
4,113,241	9/1978	Dore	266/227
4,124,506	11/1978	Dore	210/69
4,144,054	3/1979	Stary et al.	75/68 R
4,165,235	8/1979	Dantzig et al.	75/93

Primary Examiner—Thomas G. Wyse
Attorney, Agent, or Firm—Janine J. Weins; Michael J. Weins

[57] **ABSTRACT**

An apparatus and method for filtering molten metal is disclosed. The apparatus includes a crucible, a portion of which is a porous filter material. Attached to the rim of the crucible is a shock resistant ring. The crucible is positioned such that the porous filter material is submerged in the molten metal, and the rim is held above the surface of the molten metal by a brace which is attached to a fixed bracket.

The molten metal is filtered by seeping through the

Figure 11: Daniel Groteke Garage Patent

On April 20, 1984, he and Avery Kearney, living in Cincinnati, Ohio and Valparaiso, Indiana respectively, jointly file for a patent for “Molten Metal Transfer Crucible with External Filter” (Groteke and Kearney, 1986). In Figure 12, I can see that this patent is assigned to Metcast Associates, based in Cincinnati, Ohio.

United States Patent [19] — **Groteke et al.**

[11] **Patent Number: 4,564,175**

[45] **Date of Patent: * Jan. 14, 1986**

[54] **MOLTEN METAL TRANSFER CRUCIBLE WITH EXTERNAL FILTER**

[75] Inventors: **Daniel E. Groteke**, Cincinnati, Ohio; **Avery L. Kearney**, Valparaiso, Ind.

[73] Assignee: **Metcast Associates, Inc.**, Cincinnati, Ohio

[*] Notice: The portion of the term of this patent subsequent to Apr. 24, 2001 has been disclaimed.

[21] Appl. No.: **602,508**

[22] Filed: **Apr. 20, 1984**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 398,406, Jul. 14, 1982, Pat. No. 4,444,377.

[51] **Int. Cl.**⁴ **C21C 7/04**

[52] **U.S. Cl.** **266/227**; 266/275; 222/603; 222/629; 222/591

[58] **Field of Search** 266/227, 229, 275; 222/591, 603, 604, 605, 629

[56] **References Cited**

4,113,241	9/1978	Dore	266/227
4,394,271	7/1983	Groteke	266/227
4,444,377	4/1984	Groteke et al.	266/227

Primary Examiner—L. Dewayne Rutledge
Assistant Examiner—Robert L. McDowell
Attorney, Agent, or Firm—Janine J. Weins; Michael J. Weins

[57] **ABSTRACT**

The molten metal transfer crucible of the present invention filters molten metal during transfer of the molten metal to a receptacle such as a mold. The molten metal transfer crucible of the present invention is fitted with an external removable filter blade. The removable filter blade contains a filter element and is positioned with respect to an inlet in the transfer crucible such that molten metal is filtered by passing through the filter element contained in the blade while the crucible is being filled with molten metal. During operation molten metal can be intermittently back-flushed through the filter element contained in the blade. Back-flushing molten metal through the filter element extends the life of the filter element, and thereby increases the hours the transfer crucible may be operated between blade changes.

Figure 12: Daniel Groteke Entrepreneur Patent

Next, website Bizapedia.com provides a resource for searching business names and individuals involved in incorporating businesses across the United States. Figure 13 demonstrates one such result. From this search, it is clear that Metcast Associates was founded on June 24, 1976, registered in Ohio, and owned by one principal – Daniel E. Groteke (Bizapedia, 2016). The information is in line with the patenting behavior but demonstrates that the entity was founded prior to the garage invention patent that had been personally assigned by the inventor.

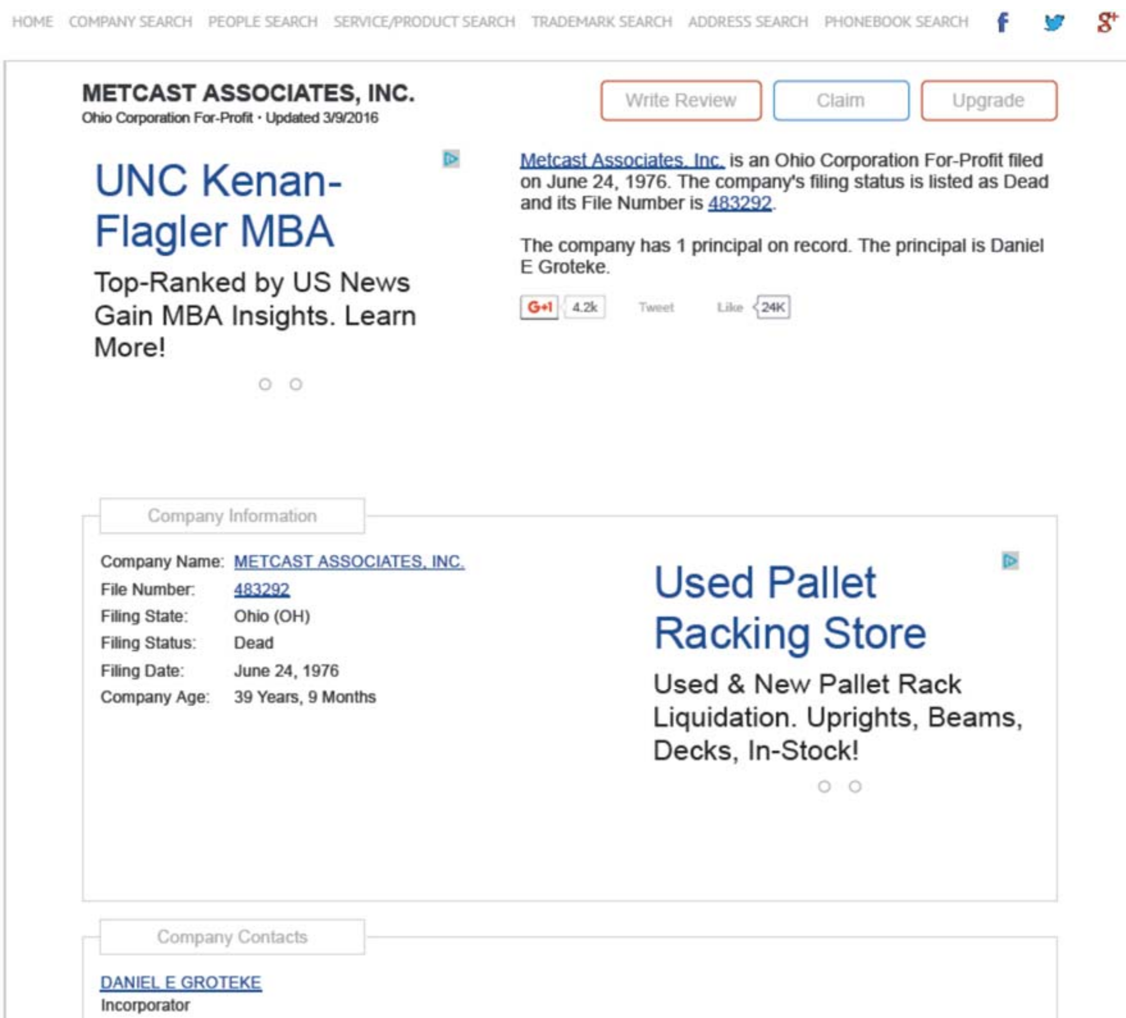

Figure 13: Example Search Result Showing Metcast Associates Founding Date

3Sixty Technologies, LLC

Another test with Bizapedia verification comes from Albert E. Johnstone. He and Frank Ratliff develops a patent 7,107,725 in 2001 for “Swivel joint apparatus and method for utility supply to a rotatable building,” originally assigned to Albert and Janet Johnstone. By the time the patent is granted in September 2006, Johnstone assigns it to the new company, 3sixty Technologies (Johnstone III and Ratliff, 2006). On May 31, 2006, he, Frank Ratliff, David A. Berg, and Michael L. Rogers file for the first patent to be originally assigned to this new company also (Ratliff et al., 2009). From the Bizapedia results in Figure 14, I can see that 3Sixty Technologies, LLC was founded on May 25, 2006 by Al Johnstone, living in La Mesa, California, and David A. Berg living in Henderson, NV (Bizapedia, 2015). Albert Johnstone was the hobbyist and visionary for rotating buildings, designing the technology and the building himself. David Berg saw a news article about the Johnstone family house, the first test of the technology, and partnered with Johnstone and his colleagues between 2004 and 2006 to form the new 3Sixty Technologies as its CEO.

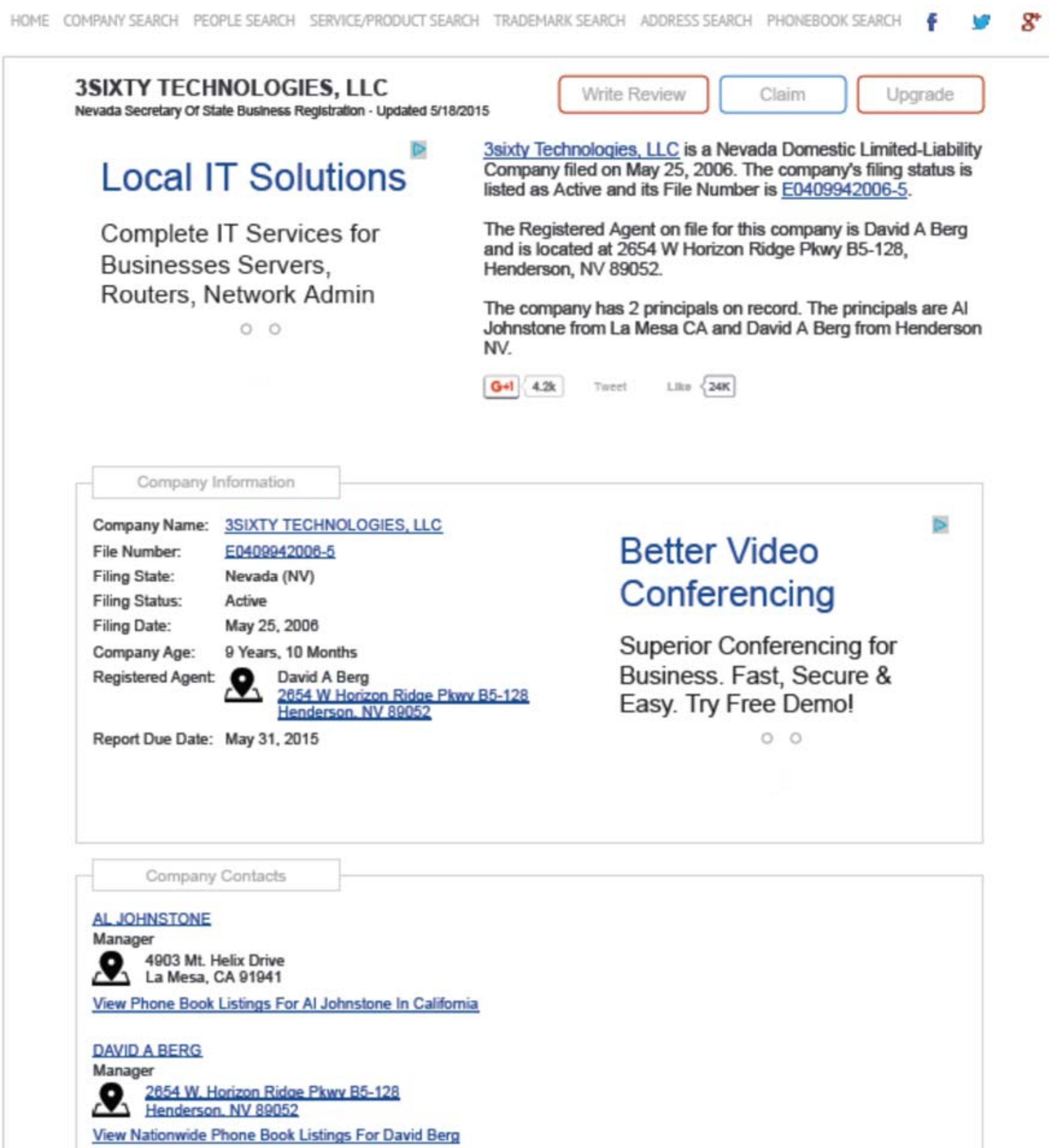

Figure 14: Example Founding Information for 3sixty Technologies, LLC

Innovative Sports, Inc.

US005678344A

United States Patent [19]

Jones et al.

[11] **Patent Number:** **5,678,344**

[45] **Date of Patent:** **Oct. 21, 1997**

[54] **FIREARM CASING DEVICE**

[76] Inventors: **Brent Jones**, P.O. Box 2267, Greer, S.C. 29652; **Robert Lawrence Parker**, Rte. One, Box 204, Clarkshill, S.C. 29821; **Phillip Durham**, P.O. Box 2267, Greer, S.C. 29652

[21] Appl. No.: **669,000**

[22] Filed: **Jun. 24, 1996**

[51] **Int. Cl.**^{6} **F41A 35/04**

[52] **U.S. Cl.** **42/96**

[58] **Field of Search** 42/96; 206/317

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2,364,340	12/1944	Bogg, Jr.	42/1
3,437,247	4/1969	Gantress	324/2
3,574,965	4/1971	Seiger	42/1
3,665,990	5/1972	Hefner, Jr.	150/52 R
3,701,371	10/1972	Stackhouse	150/52 R
3,865,166	2/1975	Pedro	150/52 R
4,280,644	7/1981	Shindelka	224/149
4,328,633	5/1982	Pachmayr et al.	42/74
4,433,500	2/1984	Kunevicius	42/1 N
4,644,987	2/1987	Kiang	150/52 R
4,754,498	7/1988	Stinemates	2/17
4,756,456	7/1988	Schauer	224/150

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235290 9/1910 Germany .

Primary Examiner—Charles T. Jordan

Assistant Examiner—Meena Chelliah

Attorney, Agent, or Firm—Hardaway Law Firm PA

[57] **ABSTRACT**

A casing for protecting firearms from the elements while allowing the user to access firearm sight and trigger. Although the firearm is at all times fully enclosed in the cover, the firearm may be aimed and discharged without having to remove the firearm from its protective casing.

12 Claims, 3 Drawing Sheets

Figure 15: Brent Jones Garage Patent 5,678,344

Innovative Sports, Inc. is a company that appears in the patent database for the first time on a patent filed for in 1998. Brent Jones had an original patent, viewed in Figure 15, for "Firearm Casing Device" with colleagues in 1996, granted in 1997, which is assigned to three co-inventors (Jones, Parker, and Durham, 1997).

US006119388A

United States Patent [19]

Jones et al.

[11] **Patent Number:** **6,119,388**

[45] **Date of Patent:** ***Sep. 19, 2000**

[54] **FIREARM CASING DEVICE**

[75] Inventors: **Brent Jones**, Greer; **Robert Lawrence Parker**, Clarkshill; **Phillip Durham**, Greer, all of S.C.

[73] Assignee: **Innovative Sports, Inc.**, Greer, S.C.

[*] Notice: This patent is subject to a terminal disclaimer.

[21] Appl. No.: **09/082,591**

[22] Filed: **May 21, 1998**

[51] **Int. Cl.**^{7} **F41A 35/04**

[52] **U.S. Cl.** **42/96**

[58] **Field of Search** 42/96, 74; 206/317; 33/244

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4,644,987	2/1987	Kiang	42/96
4,649,973	3/1987	Uchin	206/316.2
4,754,498	7/1988	Stinemates	2/17
4,756,456	7/1988	Schauer	224/150
4,858,361	8/1989	White	42/96
4,860,479	8/1989	Easter	42/96
5,016,793	5/1991	Derkatz	224/627
5,642,585	7/1997	Watley	42/96
5,661,920	9/1997	Evans	42/96
5,678,344	10/1997	Jones et al.	42/96

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235290 9/1910 Germany .

Primary Examiner—Charles T. Jordan

Assistant Examiner—Denise J Buckley

Attorney, Agent, or Firm—Dority & Manning, P.A.

[57] **ABSTRACT**

Figure 16: Innovative Sports Garage Entrepreneurial Patent 6,119,388

In 1998, they follow up with patent 6,119,388 (Jones, Parker, and Durham, 2000), further improving the line of firearm casing device, and assigned to their new company, Innovative Sports, Inc. This patent was filed on May 21, 1998 and granted on September 19, 2000. Through detailed search, a news article from the *Spartanburg Herald Journal*, presented in Figure 17, highlights their founding in 1997 and early business details (Orr, 1999), which is after the trio's first patent and before their second application.

3/21/2016 Innovative Sports sets its sights on success | GoUpstate.com

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Innovative Sports sets its sights on success

SUSAN ORR

Published: Saturday, June 19, 1999 at 3:15 a.m.

Last Modified: Saturday, June 19, 1999 at 12:00 a.m.

Page 2 of 2

Formed in 1997, Innovative Sports markets and distributes Gunbrella products, a line of waterproof camouflage covers for rifles, shotguns, bullets and bows and arrows. The covers are made of a laminated poly-nylon fleece, secured with hook-and-loop fabric fasteners. Their purpose is twofold -- to camouflage a hunter's weapon and to protect it from the elements. Innovative Sports holds the patent on the Gunbrella products, which are a simple yet new concept in hunting gear, said company president Kelly Parker, 33. When she first heard of the product, which was developed by two hunters, Parker said, she thought, " 'Why didn't somebody think of it before?' Because they've always needed it. " Innovative Sports has also developed a gun cover that fits M-16s, the standard firearm of the United States Army, and Parker said she's confident her company will get a contract to supply Gunbrellas to the military. "They are very interested," Parker said. Gunbrella's first product, its rifle cover, has earned a seal of approval from the North American Hunting Club, based on good reviews from club members who field-tested it. Innovative Sports sells most of its products to distributors, though it also markets directly to hunters through magazine and cable television advertisements. The company also sells to dealers. Innovative Sports has sold more than $100,000 worth of Gunbrella products since the company began shipping products in July 1998, Parker said. Though Innovative Sports has not yet turned a profit, Parker said the company should begin operating in the black by the end of the year. Currently, three Upstate sporting-goods stores carry Gunbrella products, including Oshman's in Greenville. The chain will test-market Gunbrellas in 10 of its stores that do the highest volume in hunting gear, and if the product does well, it will be carried in Oshman's chainwide. Another local retailer is The Totem Pole, a Union sporting goods store that stocked Gunbrella products for deer season last fall and turkey season this spring. Store owner Tommy Bell called the Gunbrella a popular product. When he showed the product to customers, he said, "nine out of 10 of them took it out the door." "I don't think there is anything out there that compares with it," Bell said of the Gunbrella. Other companies do offer gun covers, he said, but they cover only the stock of the gun -- not the entire weapon, as the Gunbrella does. Bell said he plans to place another Gunbrella order next hunting season. "I foresee it to be an oncoming item," he said. "I think it's going to get bigger as it gets more exposure." Innovative Sports is already working on a new line of Gunbrella hunting accessories that should be out next year. The company's plans also include hosting a television hunting show, becoming a major military supplier and developing its own camouflage pattern. Currently, the company must pay licensing fees for the patterns it uses. Despite its big successes so far, Innovative Sports itself is a tiny operation. Parker is one of the company's three owners, along with Brent Jones and Phil Durham. She and a sales manager are Innovative Sports' only two full-time employees. The company

Figure 17: News Search Results Detailing Innovative Sports' Founding year

Example Technologies Never Associated with New Firms

For reference, Table 14 provides a random list of technologies and inventors who were never associated with a firm beyond the development of the focal independent technology. This allows insight into the control group that was at risk of firm formation but never proceeded beyond the independent technological development.

Table 14: Example Technologies and Inventors Never Associated with a New Firm

#	Patent	First Name	Last Name	Application Date	Technology
1	4317653	MARTHA S	WAHL	1/21/1980	Educational blocks
2	4340364	MILTON G	DEEMER	8/18/1980	Endodontic test file
3	4468721	STEVEN	VANDRILLA	5/11/1983	Candle assemblies employing a window sill locking leash
4	4513573	HARALD F	FUNK	9/9/1983	System for treating and recovering energy from exhaust gases
5	4541547	RONALD J	MIKNYOCKI	10/21/1983	Token or card dispenser
6	4520431	MICHAEL	FANELLI	6/11/1984	Collapsible Lantern
7	4592483	RAYMOND E	SCOUTEN	8/6/1984	Container and separate co-operating lid
8	4668250	JAN T	DRESE	6/14/1985	Process for continuously removing and recovering respectively a gas dissolved in a liquid, particularly ammonia from aqueous ammonia waste water
9	4644683	DARRELL R	JONES	7/12/1985	Method and apparatus for enhancing the pollination of alfalfa
10	4884033	NOEL P	MCCONCHIE SR	6/6/1988	Diagnostic test apparatus for electrical system of automotive vehicle
11	4846443	HARVEY C	COLLINS	7/13/1988	Floor covering installation tool
12	5021424	JENNYLYN	LAWTON WALL	6/1/1989	Vitamin composition for treatment of flea infestation in animals
13	4966320	MITCHELL	BLOOM	11/13/1989	Simulated pouch with interior, concealed holster
14	5125526	ARNOLD J	SUMANIS	11/21/1991	Waste receptacle with interior bag that is opened and closed automatically
15	5743105	KEIJIRO	YAMAUCHI	9/30/1994	Apparatus for producing ice vessel

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